43

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COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH, NEW DELHI

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Electrical and Mechanical Engineering
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CONTENTS

Creation of Design & Engineering Facilities and Manufacture of Plant, Machinery and Components ... 1
A. N. KAPUR

Equipments for the Pharmaceutical Industry ... 2
R. P. DE

Engineering Aspects ... 4
Neyveli Lignite Corporation Limited

Substitution for Requirements of Welding Electrodes Industry ... 7
V. A. ALTEKAR

Substitution of Aluminium Alloys in Chemical Industry ... 9
V. A. ALTEKAR

Chemical Plant Fabrication in India ... 11
O. P. KHARBANDA

Problems of Corrosion of Marine Chemical Process Industries and in Marine Atmosphere ... 16
K. SESHADRI

Feasibility Studies on Desalination of Seawater Plants for Industrial Cities of India ... 18
S. D. GOMKALE, R. L. DATTA & D. S. DATAR

Seawater as Coolant ... 20
S. D. GOMKALE & R. L. DATTA

Design of Process Equipments for Marine Chemicals ... 24
V. N. LELE, D. J. MEHTA & D. S. DATAR

Design of Solar Still for Sea or Brackish Water Desalination ... 28
S. Y. AHMED, S. D. GOMKALE & R. L. DATTA

Humidification-Dehumidification Technique for Seawater Desalination ... 30
S. K. GARG & R. L. DATTA

Moulded Insulation from Magnesia and Calcium Silicate ... 32
H. V. SHAH & D. J. MEHTA

Development of a Disperse Salt Washing Column ... 34
M. M. MOHIUDDIN, P. M. BHATT, R. K. SAPRE
R. L. DATTA & D. S. DATAR

CONTENTS

Design of Salt Harvester and Mechanical Soil Stabilizer for Salt Works ... 36
R. P. DHIMAN

Indigenous Design & Construction Facilities Available in India ... 37
M. T. SHAH

Need for Process Design Facilities for Chemical Plants in India ... 41
B. V. BHOOTA

Chemical Plant Design and Construction in India ... 47
S. R. POTI

Alkaline Manganese Dioxide Wet Cells ... 52
M. A. V. DEVANATHAN, N. RAMASWAMY & S. VENKATESAN

Some Aspects of Research on Batteries and their Production ... 53
H. V. K. UDUPA

Light-Weight Portable High-Energy Silver Batteries ... 57
PREM BEHARI MATHUR, N. KARUPPANNAN & R. BALASUBRAMANIAN

Research and Development for Import Substitution in Electrical Industry ... 62
K. C. LALL & S. SWAYAMBU

Glass-lining of Chemical Equipment ... 70
Regional Research Laboratory, Hyderabad

Import Substitution of Spares in Organic Chemical Industry ... 72
R. M. KHANDWALA

Titanium for Construction for Chemical Plant ... 75
S. L. CHAWLA

Research and Development: Dry Battery Industry ... 80
N. C. MEHTA

Semi-mechanized Machine for Preparing Self-set 85% Magnesia Insulation ... 85
R. N. VOHRA & B. G. THAKER

Desalting Saline Waters with Ion Exchange Materials ... 87
N. KRISHNASWAMY

Chemical Plant Designing in India — Its Role in Import Substitution ... 89
RAJESHWAR KUMAR GUPTA

Gaps in the Facilities of Chemical Plant Design in the Country ... 93
M. D. VIJAYARAGHAVAN

Capital Equipment for Chemical Industry ... 100
B. K. BANERJEE, R. B. BARTON & D. R. SUD

Self-sufficiency in Power Generating Equipment ... 105
S. SWAYAMBU & V. KRISHNAMURTHY

Creation of Design & Engineering Facilities and Manufacture of Plant, Machinery and Components

A. N. KAPUR
National Research Development Corporation of India
New Delhi

Even where the industry is convinced of the merit of industrial research, its utilization is blocked due to lack of adequate design and engineering facilities for scaling up laboratory researches to commercial project, and non-availability of plant and machinery in the country. Greater emphasis should, therefore, be laid on development of design and engineering know-how and technical skills in the laboratories should be mobilized towards designing and fabricating indigenously plant and machinery required for commercial production. It is essential that industrial research laboratories should be provided with adequate chemical and mechanical engineers and the scientists and engineers from the laboratories should be detailed to work in industrial units in the country or abroad to gain necessary training and experience in design and engineering of commercial factories. Intensive surveys should be made of the machinery manufacturing facilities in the country and industrial research laboratories should maintain close contacts with them. With the joint efforts of the Central Design & Engineering Organization, CSIR, scientists, chemical and mechanical engineers of the laboratories, technologists of industry and machinery manufacturers, it will be possible to design and supervise fabrication and erection of commercial factories and such essential components as are hitherto imported.

Equipments for the Pharmaceutical Industry

R. P. DE
Bengal Immunity Research Institute
Calcutta

The drug and pharmaceutical industry envisages a wide range of unit operations involving a variety of equipments and machinery. Although the requirement of this industry is not heavy, it is highly specialized in nature. The schedule 'M' to the Drug Rules gives an outline of basic minimum requirement of equipments and machineries for the manufacture of different types of drugs and for maintaining proper condition of the manufacturing unit. The pharmaceuticals have been classified under the following heads: (a) Ointments, emulsions, lotions and suspensions. (b) Syrups, elixirs and solutions. (c) Pills, compressed tablets including hypodermic tablets. (d) Parenteral solutions. (e) Powder. (f) Hard gelatine capsules. (g) Surgical dressings. (h) Eye ointments, eye drops and eye lotions. (i) Pessaries and Suppositories. (j) Inhalers and Vitrallae. We shall limit our discussions mainly to the non-availability of equipments/accessories needed for drugs and pharmaceutical industry and the scope of their manufacture within the country either through indigenous resources or collaboration.

For maintaining proper room condition of the parenteral solution manufacturing unit, including aseptic solutions, absolute air filters, ultraviolet lamps and all-glass pipe lines in special cases are essential. The transfer of liquids by sterile air and also sterile filtration of solutions involve ceramic candles/filters and seitz filter pads in some cases; since mechanized handling of ampoules and vials starting from washing, sterilizing, filling, sealing/seaming, sterilization, checking, labelling, packaging etc. have become more important in view of greater economy and quality of production, a move is to be made towards development of a composite unit within the country. Now that many of the drugs are packed in polyethylene containers, sterilization of these by ethylene oxide/CO_2 and also by irradiation is yet to be developed in our country.

So far as manufacture of tablets is concerned, mixers, granulators, driers and rotary tablet machine are now available from indigenous sources, but for specialized requirement of comminuting mills, rotary high speed tablet machines, fluid bed driers, tablet checking machine, we have to turn to foreign country. Homogenesiers, colloid mills needed for certain ointments, lotions, suspensions and the like, as also some of the sophisticated filling and packaging machines are not yet made in India.

Apart from these, many of the process machinery like medium/large size industrial separators, spray driers, rotary vacuum filters, pulverizers etc. are yet to be developed and made in the country.

Processing of many of the drugs involves freeze drying and also high vacuum distillations. The large size high vacuum pumps including

mechanical and diffusion type, coupled with refrigeration units and measuring instruments are not available.

Newer technology is coming up very rapidly and we must put our best efforts to be in line with the development. The use of ultrasonics for making of emulsions, use of electrophoresis on large scale for the separation of salts, use of Aerosol technique, etc. are only a few instances.

Lastly, stainless steel as a material of construction has become synonymous with the pharmaceutical industry and similarly plastic is also coming up. It is expected that we will be getting this alloy steel from our different alloy steel plants but the manufacture of high density polyethylene, propylene, PTFE etc. is also to be taken up without delay.

Engineering Aspects

Neyveli Lignite Corporation Limited
Neyveli

The Neyveli Lignite Project is an integrated one consisting of a lignite mine with an ultimate capacity of 6.3 million tonnes per annum, a thermal power station of 300 MW. capacity which is being extended to 600 MW., a fertilizer plant with an annual capacity of 1,52,000 tonnes of urea and a briquetting and carbonization plant capable of producing 3,80,000 tonnes of carbonized briquettes, besides several by-products like middle oil, tar and phenol. The mines, thermal power station and the briquetting and carbonization plant are in production and the fertilizer plant is expected to go into production shortly.

The mining is highly mechanized and employs specialized machinery including bucket wheel excavators, slewable spreaders, special belt conveyor systems, etc. for the first time in India. To control the pressure of the artesian ground water, the mining scheme employs about 50 giant pumps each of one thousand gal. per min. capacity.

The thermal power station has six units of 50 MW. each, to which will be added 3 more units of 100 MW. each. The entire thermal station is of Russian manufacture. In the fertilizer factory, equipment for the gasification, gas purification and air and gas fractionation were supplied by German firms whereas the equipment for ammonia and urea synthesis were by Italian firms. The equipment for the briquetting and carbonization plant was supplied by a consortium of West Germany and Indian Firms.

Finding foreign exchange for the import of spares has been a problem for the project for quite some time now. The complicated machinery in the various units of this project have to be kept in good maintenance if we have to get the best out of them. This is not possible without periodical annual overhauls. Adequate spares could not be procured so far to undertake this. Therefore only breakdown maintenance is being attended to.

This project is therefore concentrating on import substitution as well as indigenous manufacture. The efforts in these directions together with possibilities as far as this project is concerned are dealt below.

Substitution for imported raw materials

In the project workshops, we have been able to manufacture as many as 205 parts belonging to various machinery which were hitherto imported. These were done out of the raw steel available indigenously. On studying some of the manufactured parts, we note that the life of the local products is less than the imported ones in many cases, mainly due to the fact that we had to do with any type of steel instead of the right alloy steel used in the earlier part for two reasons : (1) we do not have the composition and (2) where we have the composition, we find that they have to be imported and the import was not possible either for want of time or foreign exchange.

If we have to improve the quality of local manufactures and thereby its economics, we should get the correct steel. It is precisely, in this context, Chemical and Metallurgical Laboratories should help They can undertake detailed chemical and metallurgical analysis of various kinds of alloy steel used in the various parts of the plant and machinery and advise the concerned Projects to explore the possibilities of procuring the correct material from indigenous sources. Where the composition of the steel has been identified, the steel plants in the country should undertake manufacture of steel of at least the nearest equivalents. Our experience has been that the foreign suppliers are reluctant to give the technical and design documentation for spares much less the composition of the steel used. The remedy therefore lies in developing our own laboratory facilities to find out the nearest equivalents.

On the electrical side, we have been able to procure indigenously the following items :

(1) Jointing materials including high tension compound, tapes for the cable jointing up to 11 kV.

(2) Bi-metal relays up to 60 amp. capacity

(3) Auxiliary relays and air-breaker contactors up to 60 amp. capacity

(4) L. T. instrument transformer

(5) Carbon brushes for motors

(6) Push button switches and other L. T. control equipments

(7) All types bushings for transformers and circuit breakers

The above materials were hitherto imported.

The suppliers of belts require import licence for importing nylon and rayon yarns for the manufacture of belts indigenously. We may be requiring about Rs 8 lakhs worth of nylon and rayon yarns to meet the requirement of belts per year. Another major raw material for this project is the special bracing material for building up our Bucket Wheel Excavator teeth. Table 1 gives the description of the raw materials and the approximate quantity required per year.

It would be very helpful if the national laboratories could help to give the composition of the various materials or suggest effective alternatives.

Indigenous manufacture of essential components hitherto imported

Some of the suppliers of the main equipment have started manufacture of part of the range of equipments in India; e.g. Messrs K. S. B. These manufacturers are reluctant to supply spares as they would like to divert their efforts in supplying complete equipment. Even our efforts to get the public sector undertakings to help us have not been very fruitful especially Mining and Allied Machinery Corporation. The following components were attempted to be procured indigenously:

(i) Gear boxes for conveyors, excavators and spreaders

(ii) Idlers and Idle shafts

(iii) Bearings and housings and pulleys and pulley shafts

Attempts are being made for the indigenous manufacture of about 90 per cent of the fast wearing spares limiting the imports only to the items

Table 1 — Raw materials and approximate quantity required annually

Sl. No.	Description of materials	Quantity
1.	Nylon and Rayon yarn	Rs 8 lakhs worth
2.	Breaker-fabric	1964 lb.
3.	En 8 Carbon Steel	650 kg.
4.	Carbon-manganese steel 2 in.	100 kg.
5.	High carbon steel 8 in. diam.	4 T.
6.	Steel rounds	2 T.
7.	German steel plates (wear plate)	50 T.
8.	High carbon alloy steel	Rs 1500 worth
9.	Boiler special steel rods	Rs 2200 worth
10.	Stainless steel sheets	Rs 3225 worth
11.	Bohler Electrodes	360 M
12.	Soldering foil wire cloth No. 60	Rs 2000 worth

TEETH AND BRAZING MATERIALS

Teeth inserts

Widias Code No. 7492/2		18,188
Widias Code No. 7492/3		6,527
Widias Code No. 7495/4		3,572
Widias Code No. 7495/5		2,955
Widias Code No. 2.206260		10,534

Teeth holders (for Big Bucket Wheel Excavator)

A	Corner teeth	214
B	Side	596
C	Ripper	421
D	Ripper teeth	456
E	Side	493
F	Corner teeth	215
	TOTAL	2395

Brazing materials

1.	Verdur rods	2440 kg.
2.	Soldering nickel mesh	210.6 sq. m.
3.	Rupatam 'A' Foil	175.5 kg.
4.	Rupatam 'A' Flux	70.2 kg.
5.	'Cekas' binding wire	70.5 kg.
6.	Flux	50.0 kg.

required for capital overhaul and repairs. For items like bearings, oil seals, wire ropes etc. inter-changeability list has been prepared for the various types of machinery in the Corporation and bulk orders are being placed for their local procurement.

Substitution for Requirements of Welding Electrodes Industry

V. A. ALTEKAR
Department of Chemical Technology
Bombay

The problem of obtaining raw material requirements of the Indian electrodes industry has become very acute with the dynamic growth of this industry during the past decade. If this industry is to be allowed to keep its growth related to the steel production in India and if its strategic importance is to be fully realized, then it is necessary to project the needs of this industry and to provide for them from indigenous sources. This paper reviews the requirements of various items and suggests prompt implementation of the successful research schemes carried out by our national laboratories and institutions.

Core wires. A couple of years ago the dearth of core wires was a serious problem with this industry, since all the requirements were imported. This was so because the specifications were very high and rigid and could not be met by local producers. The steel core wire, which has to be of rimming steel, must have sulphur and phosphorus less than 0.03 per cent which is also the limit for silicon, carbon 0.1 per cent max.; copper 0.15 per cent max. and manganese 0.4 – 0.6 per cent. The wires are needed in gauges 4 to 16, and the projected demand by the end of the Fourth Plan period will be about 50,000 tons per annum. Recently, Bhilai steel plant has earnestly taken up the manufacture of the bulk of the wire requirements, although their product costs about 40 per cent higher than the landed c.i.f. price of imported steel. This turnover itself is about Rs 70 million per year.

Rutile. Among the flux ingredients, rutile is the most important with a projected demand of about 12,000 tons per annum. The mineral rutile exists in appreciable amounts in the beach sands of Travancore, although very little has been done so far to increase the production of rutile from the present feed to the plants. The small local production is sold to the electrode industry at almost double the price of the imported Australian variety.

A process developed by the author enables upgrading of the abundantly available ilmenite to the rutile grade. Samples of such synthetic rutile have been tested by the industry and have been found satisfactory. There is scope for a Rs 8 to 10 million turnover of this item.

Low-carbon ferro-alloys. All the needs of low-carbon ferro-manganese and ferro-chromium have been imported in spite of the development work done by the National Metallurgical Laboratory. The ferro-manganese requirements amount to 2,500 tons per year and its specifications are 80 per cent Mn min., and 1.0 per cent carbon max. The cost of imported item amounted to Rs 2,500 per ton inclusive of duty. The turnover of this item is about Rs 5 to 7 million per year.

Low-carbon ferro-chromium must contain 65 per cent Cr, and 0.1 per cent C max. It is needed to the tune of about 100 tons per year in powder form. The cost of imported powder was about Rs 5000/ton per year, with a turnover of Rs 5 lakhs.

High-carbon ferro-alloys. Ferro-manganese of this type must have 80 per cent Mn, should be of 80 mesh and is needed to the extent of 2000 tons per year. High-carbon ferrochromium containing 4/6/8 per cent carbon and 60–65 per cent Cr is used up to 200 tons per year and imported at a rate of Rs 3000/ton. A low gassing variety of ferro-silicon containing 45 per cent Si, and 0.1 per cent C max., is needed in 200 mesh size to the extent of 1000 tons per year. Besides, 12 tons each of electrolytic Mn and Cr powders (80–100 mesh) at Rs 6500 and Rs 13,500/ton (c.i.f. Bombay) are needed. It is worthwhile to start the manufacture of these items in right earnest.

Substitution of Aluminium Alloys in Chemical Industry

V. A. ALTEKAR
Department of Chemical Technology
Bombay

The chemical industry is a major consumer of special metals and alloys with uncommon specific properties which demand not only structural strength, but simultaneous resistance to specific corrosive conditions. A great number of ferrous and nonferrous alloys, mostly imported, have been developed to meet these specific needs. A major bulk of these is made up of stainless steels, copper, nickel and their alloys, lead, tin, zinc, the rare metals and their alloys. Stainless steels with their wide resistance to corrosion through a large number of grades are suggested as first impulse to confrontation of a problem. A better understanding of the nature of stainless steels should indeed serve as a brake to their indiscriminate use.

Chemical stability of aluminium. The heat of formation of its oxide (389 kcal. per mole) suggests a highly unstable metal. However, an everpresent, self healing, impervious, adherent, hard, and an almost invisible film of its oxide makes aluminium exceptionally stable under a surprisingly wide variety of chemical environments. Conditions which will attack and dissolve away this oxide film, or conditions which will promote oxygen starvation, or which set up oxygen concentration cells, are disastrous to the metal. This oxide film can be synthetically produced by chemical or electrochemical treatment to obtain a wide group of enhanced properties. It is no exaggeration to say that the metal owes its commercial existence to this film.

Galvanic considerations. The electrode potential of aluminium is very high in comparison with most other metals, except zinc and magnesium. In brine, aluminium alloys range from 0.96 V to 0.70 V as against 1.0 V for Zn, 0.2 V for Cu and 0.07 V for Ni. Contacts with other metals set up cells wherein the Al alloys are anodically corroded away.

Even within itself, an alloy is likely to contain areas highly anodic or cathodic to its surroundings, resulting in heavy pitting type or intergranular attack. Mn, Mg and Si alloying elements do not induce harmful micro-constituents. But Fe, Cu, Ni, form strongly cathodic areas. Phase precipitation makes certain alloys sensitive to heat-treatment.

Alloys and their properties. ASTM code allows the use of Al alloys for pressure vessels up to 150 p.s.i.g. up to 200°C. Cryogenic properties of Al are worth noting. The tensile strength and percentage elongation both increase with drop in temperature.

Processing equipment for chemicals. Aluminium alloys are extensively used for acetic acid, acetic anhydride, ammonium hydroxide and carbonate, nitrate, amines, edible oils and fats, fatty acids, formaldehyde, hydrogen peroxide naval stores, refrigeration and refrigerant handling, soda-ash, waters of all types, nuclear technology uses, petroleum production,

petroleum refining, petrochemical industries, dairy, brewery, tannery, etc. in a variety of forms like stills, distillation columns, heat exchangers, reaction vessels, evaporators, crystallizers, piping, drums, tanks, tank-cars, condensers, pumps, scrubbers, deodorizers, bleachers, etc.

Fabrication, safety, costs. Being lighter and softer, Al is easy to install and form. It has a very good safety record being non-sparking. Comparing alloy 5456 with alloys 3003, 304, 316, and copper in allowable stress (10,400; 3150; 17,700; 18,750; and 6700 p.s.i.), their metal density (0.096, 0.099, 0.29, 0.29, and 0.32) their prevalent price (US$ 0.542, 0.449, 0.547, 0.807 and 0.57/lb.), the metal cost per vessel of each works to 100, 282, 180, 252, and 546 (for copper).

Chemical Plant Fabrication in India

O. P. KHARBANDA
Larsen & Toubro Ltd
Bombay

A decade ago, chemical plant and equipment were almost entirely imported. As a result of the initiative of the Indian entrepreneurs and Government's declared policy to encourage manufacture, several workshops have already been established in various parts of the country. This has resulted in a five-fold increase in the indigenous production of chemical plant and machinery over the period 1960–65, but even now imports are quite substantial as shown in Table 1.

It must be pointed out that several somewhat inconsistent data have appeared in literature, the discrepancy being because of lack of a clear definition of the term 'chemical plant and equipment'. The figures noted above have been taken from official sources and are exclusive of cement, paper and sugar machinery. The total estimated current production (1965–66) as also the Fourth Plan (1970–71) targets of production for various categories of chemical and allied machinery are shown in Table 2.

Table 1 — Indigenous production and imports value of chemical plant and machinery during 1960-65

(Value Rs crores)

	1960-61	1961-62	1962-63	1963-64	1964-65
Indigenous	1.4	3.2	4.6	6.0	6.7
Imports	3.5	5.0	9.7	8.1	—
% Imports	72	61	68	57	—

Table 2 — Estimated current and fourth plan production target

Type of machinery		1965-66 estimated (1)	1970-71 target (2)	(2)/(1)
Chemical*		11	36	3.3
Cement		5	28	5.6
Paper		7	30	4.3
Sugar		12	22	1.8
	TOTAL	35	116	3.3

* Includes machinery for fertilizer, heavy chemical and petroleum but not for petrochemical industries

Thus, in the Fourth Five-Year Plan production is likely to increase three-fold and it now appears that the industry has reached the take-off stage.

Present position

Chemical plant fabricators appear to be concentrated in the western region, although the total production in the eastern region appears to be greater. This is shown in Table 3.

The analysis is entirely in respect of Chemical Plant Manufacturers' Association of India (CPMAI) members. The detailed geographical location of the members is indicated below:

Ahmedabad	2	Madras	1
Baroda	2	Poona	2
Bombay	19	Vallabh Vidyanagar (Gujarat)	1
Calcutta	7	Yamunanagar (Ambala)	1
Delhi	1		
Durgapur	1		
Kansbahal	1	Total	38

Several workshops are in a position to handle materials other than mild steel. The capabilities of various workshops vary considerably and these are being constantly extended by providing additional facilities. Table 4 summarizes the scope and extent of current indigenous manufacture in respect of carbon steel and stainless steel pressure vessels and heat exchangers*.

Table 3 — Chemical plant fabricators

Region	Location	No. of workshops	Production (Rs crores)
Calcutta	Calcutta, Durgapur, Kansbahal	9	16
Bombay	Bombay, Ahmedabad, Baroda, Poona, Vallabh Vidyanagar	24	14
Delhi & Madras	Delhi, Yamunanagar, Madras	3	4
	TOTAL	36	34

Table 4 — Indigenous manufacture of pressure vessels and heat exchangers

	Pressure (atm.)	Thickness (mm.)	Remarks
Vessel:			
Mild Steel	Around 1	6-20	Missing links are dished ends, rings, flanges, etc.
	Up to 30	20-75	Inadequate capacity
	300-500	Over 75	Practically non-existent
Stainless Steel	7-8	2-7	Adequate capacity
	Above 8		Inadequate capacity
Heat Exchanger:	Up to 30		Inadequate facilities
Mild or Stainless Steel	Above 30		Non-existent

*For conditions normally encountered for a typical nitrogenous fertilizer plant of capacity 0.1 million tons N per year

The present status of fabrication facilities available in India can be summarized thus :

Welding — Many workshops have installed bevelling machines for plate thicknesses even above 25 mm. An increasing number of shops are using semi-automatic welding machines such as submerged arc welding, argon arc welding, CO_2 welding etc.

Rolling — Rolling facilities for plate thicknesses up to approximately 75 mm. are available at a few workshops.

Dishing — Some loading fabricators make dished heads in one operation by hot pressing.

Machining — All the modern workshops have machines for horizontal boring, vertical boring and milling (up to 4500 mm. diam.), gear cutting (for larger diam.), firth gearing etc., and heavy duty long bed lathes.

Stress relieving — This is carried out by large workshops in Bombay, Calcutta, Ahmedabad and Durgapur etc.

Testing — Facilities are available for pneumatic or hydrostatic testing with ammonia or sulphur dioxide etc., and also for non-destructive tests such as gamma ray, dye penetrant, magnetic flux, ultrasonic etc.

Missing links and problems

These may briefly be mentioned as follows :

Raw material. The raw material position generally is not encouraging. Mild steel, copper and commercial quality aluminium are available locally. Indian steel is usually untested, qualitatively below ISI specification, often laminated, not normalized after rolling and is available in very uneconomic sizes. The production of copper and commercial quality aluminium falls far short of demand. Material such as stainless steel, monel, nickel, titanium, and admiralty or navel brass are imported. Quotas sanctioned are much smaller than the requirements, there are numerous formalities to be completed and issue of licences is considerably delayed. Important consumables such as welding electrodes are produced in quantities much smaller than the demand and thus hinder the progress of the industry.

Workshop facilities. At present adequate capacity for production of dished and pressed parts for 60–75 mm. thickness is not available. Additional capacity is required for fabrication of vessels and heat exchangers for medium and high pressure duty, in particular drilling and tube expanding facilities have to be increased. More furnaces, for stress relieving of 4 m. diam. × 20 m. long vessels in neutral atmosphere, are required. Testing facilities, in particular of the non-destructive type, are completely insufficient to meet the current requirements.

Process design. The present facilities for process design in India are very limited and it is essential that for a rapid growth of the chemical plant manufacturing, corresponding process design facilities are also developed. The Association is already seized with this problem.

Standardization. Standardization of raw materials, components and equipment can help the industry to improve the quality, lower cost of production and cut down on delivery time. It can also help reduce inventory holding, material wastage and installation cost. Indian Standards Institution has already made valuable contribution in the standardization of raw materials and components, but for standardization of equipment only a beginning has been made. For items such as process vessels and heat exchangers, draft standards are in the course of preparation.

Future requirements

This is extremely difficult to gauge because of the uncertainty of achieving targets set for various chemicals. Past performance, particularly during the current Plan period, has not been very encouraging, as shown in Table 5.

Assuming arbitrarily, using past performance as a guide, that the Fourth Plan targets (1970–71) indicated below are attained to the extent of 80 per cent for cement, fertilizer and paper, and to the extent of 100 per cent for petroleum, heavy chemicals and sugar, it is possible to arrive at the estimated total requirements of plant and machinery for major sectors of the chemical and allied industry. This is represented in Table 6.

To the total must be added approximately Rs 200 crores worth of plant and equipment for the nascent petrochemical industry. The target

Table 5 — Comparison of targeted and actual capacities

(Capacity : million tons per year)

	1960-61		1965-66		1970-71 Target
	Target	Actual	Target	Actual*	
Fertilizer					
N	0.38	0.16	1.00	0.59	2.30
P_2O_5	0.12	0.10	0.50	0.25	1.00
Heavy Chemicals					
Caustic soda	0.15	0.12	0.40	0.33	0.65
Soda ash	0.25	0.27	0.53	0.36	0.70
Sulphuric acid	0.50	0.52	1.75	1.40	3.50
Petroleum	—	—	17.25	15.25	22.75
Cement	11.00	9.2	15.00	13.00	25.00
Paper & Pulp	0.44	0.39	0.97	0.68	1.74
Sugar	—	—	3.50	3.25	4.50

* Anticipated

Table 6 — Requirements of plant and machinery for chemical and allied industries

(Million tons/year)

	Estimated capacity*		Additional capacity	Plant cost	
	1965-66 (1)	1970-71 (2)	(2—1)	Rs/ton year	Rs crore
Fertilizer					
N	0.59	1.84	1.25	1500	188
P_2O_5	0.25	0.80	0.55	100	6
Heavy Chemicals					
Caustic soda	0.33	0.65	0.32	750	24
Soda ash	0.36	0.70	0.34	60	21
Sulphuric acid	1.40	3.50	2.10	60	13
Petroleum	15.25	22.75	7.50	80	60
Cement	13.00	20.00	7.00	150	105
Paper & Pulp	0.68	1.40	0.72	1650	120
Sugar	3.25	4.50	1.25	500	63
				TOTAL	600

Table 7 — Target production and anticipated requirement
(Value Rs crores)

	1970-71 target	Requirements	Imported*	Indigenous
Chemical	36	512	154	358
Cement	28	105	16	89
Paper	30	120	36	84
Sugar	22	63	13	50
TOTAL	116	800	210	581

* On the basis of imported content of 15 per cent for cement, 20 per cent for sugar, and 30 per cent for chemical and paper machinery

production of plant and machinery can now be compared with the anticipated requirements during 1966–71 as in Table 7.

The current total production under the above categories is valued at Rs 35 crores. Assuming a linear rate of increase during the Fourth Plan period, the total anticipated production will be of the order of Rs 380 crores. Of the total requirement of Rs 800 crores worth of machinery, probably 20 per cent represents the cost of electricals, boilers and castings etc. The anticipated production (Rs 380 crores) will, therefore, fall short by 10 per cent of the entire requirements (Rs 420 crores) of chemical and allied machinery during the Fourth Plan period. This shortfall is not significant since workshops can easily produce 10 per cent above their capacity. It is also possible that figures assumed for achievement of targets are too optimistic. It should be noted that workshops equipped to manufacture unit operation equipment can easily be geared to the particular needs of any chemical or allied industry and thus provide for a built-in flexibility in production.

Conclusion

The present survey indicates the development of chemical plant manufacture in India. The existing facilities, missing links and future requirements are indicated with appropriate corroborating figures. It is certain that given the necessary raw materials and an incentive for expansion the industry's future growth will be phenomenal. The industry is poised for a take-off and the intended growth will require considerable initiative and capital investment.

Problems of Corrosion of Marine Chemical Process Industries and in Marine Atmosphere

K. SESHADRI
Central Salt & Marine Chemicals Research Institute
Bhavnagar

Corrosion is a serious problem particularly in salt and marine by-product process industries. Processes involving evaporation, extraction and crystallization where concentrated liquors containing corrosive salts are handled at higher temperature, the problem becomes more acute. The abrasive action of hard crystalline material on the metallic surface enhances the corrosion problem. Hence, choice in the selection of suitable material of construction is very much limited. Monel metal is usually satisfactory and has become a standard material for use in contact with wet salt, brine and bittern. Stainless steel, particularly alloyed with small amount of molybdenum has proved excellent because of its greater hardness and resistance to abrasion. However, use of these is often prohibitive in salt and by-product process industries as they increase the capital investment and the end products are generally cheap materials of commerce.

Corrosion of metals and alloys in different densities of brine are being studied in the Institute. Rate of corrosion of mild steel in 36° Bé bittern in cold as well as hot is high. Influence of inhibitors showed that potassium chromate (0·1 per cent) prevents the rate of corrosion of mild steel at 100°C. to a remarkable degree. The above observation will be assessed in actual process connected with salt and by-product industries.

The cheap material of construction, mild steel, corrodes in contact with brine and quite rapidly with bittern containing magnesium chloride. Even monel and stainless steel are not quite satisfactory particularly with high density bitterns containing high concentration of magnesium chloride at high temperature (worst at boiling temperature).

A serious corrosion problem is encountered in extraction of potassium chloride from mixed salt by 36 Bé bittern by the process developed in this Institute (Indian Pat. No. 67461, 1959). In order to decrease the cost on equipment, a corrosion study was undertaken and in course of study, it is realized that although mild steel is not able to combat corrosion by itself, it can be used if it is protected by surface coatings. In this connection chemical resistant paints, various anticorrosive paints (indigenous) were tested for their suitability.

Epoxy paints of indigenous make, gave satisfactory results as anti-corrosive paint for inner surface coatings of equipments handling high temperature bitterns. For the selection of suitable material of construction for the re-crystallization of impure potassium chloride at 110°C. by saturated solution of $NaCl + KCl$, corrosion study of mild steel, aluminium and copper was done and copper and aluminium were not found suitable.

Studies on atmospheric corrosion of metals at Bhavnagar completed for the year 1964 to 1965, showed that the rate of corrosion of mild steel at Bhavnagar is mild when compared to other marine-cum-industrial cities of India. The study will be continued at the instance of Central Advisory Corrosion Committee at Bhavnagar and other places in Saurashtra.

Comprehensive studies on the corrosion problems of salt and by-product industries and generally of other industries using seawater are being planned with a view to undertake new studies besides extending the present investigations.

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Feasibility Studies on Desalination of Seawater Plants for Industrial Cities of India

S. D. GOMKALE, R. L. DATTA & D. S. DATAR
Central Salt & Marine Chemicals Research Institute
Bhavnagar

Feasibility studies being carried out on the selection of desalination plants suitable for high water requiring industrial cities like Bombay, Madras and Kandla tentatively indicate that there is a possibility of humidification-dehumidification technique becoming useful for million gallons capacity range, and that flash distillation or forced circulation vapour compression technique may be applied using nuclear power, a source of cheap power. Dual purpose plant producing both fresh water and power will make fresh water still cheaper. Recovery of bromine, a costly by-product of discharged brine from such a plant will improve the economy of fresh water production further.

Industrialized cities like Bombay and Madras and places under development like Kandla have water shortage problem of very high magnitude as shown below:

	Bombay	Madras	Kandla
Present water supply (m. gal./day)	212.0	35.0	2.0
Water requirement by 1970 (m. gal./day)	530.0*	62.0	12.0

Additional requirement of water of about 320 m. gal./day at Bombay is proposed to be met by different schemes (sources at distance of 75 miles or more) at prohibitive cost of Rs 122 crores. Alternative sources thought of for Madras do not look prospective. Proposed industrial development at Kandla may have to be abandoned on account of water shortage. In view of the circumstances, desalination of seawater may lend support towards solution of the problem of water shortage for these cities.

Of the several techniques of desalination of seawater known and in the process of development, the possibilities of application in India may be out of (1) solar still, (2) humidification-dehumidification, (3) flash distillation or (4) forced circulation vapour compression distillation techniques. Selection of one or the other of the techniques will mainly depend on the water requirement. Solar still is useful in certain places such as salt farms or islands where water cost is high and where fuel or power is not available but solar energy is abundant for a longer period of the year. Solar stills are however suitable at places where water requirement does not exceed 20,000 gal./day.

The humidification-dehumidification unit coupled with solar collector requires some power (about 27 kWh per 1000 gal. compared to 10 times

*For 1980

this value for flash distillation) and is more suitable than solar still beyond a capacity of 20,000 gal. of fresh water per day. Feasibility of such a technique for capacity of a million gallons of water per day or more is under examination.

When the requirement of water is in several million gallons per day, as in Bombay, Madras and Kandla, flash distillation or forced circulation vapour compression distillation technique may be applied. Cost of fresh water by such techniques is 5 to 6 times that of conventional water. Investment cost per 1000 gal. of water for such a plant is nearly Rs 7580 compared to Rs 8260 for humidification-dehumidification plant. As high as 50 per cent of water cost is to power alone. Use of nuclear power which is estimated to be 2.5 paise per kWh will reduce cost of fresh water considerably.

Dual purpose plants producing both power and desalinated water will be economical in places like Madras where there is shortage for both water and power. In this case ratio of power and water production in the plant needs to be fixed according to demand. In such plants low pressure exhaust steam from turbines is used in the desalination plants. By proper allocation of cost to power and to water produced, water cost works out cheaper than that obtained by single purpose desalination plant.

If a nuclear power plant is coupled with desalination plant, the cost of converted water will be still less, as for such a plant also serving as dual purpose plant. The power available for desalination will be cheaper. Establishment of atomic power plants at Tarapore (Bombay) and Kalpakam (Madras) will enable the working of desalination plants on this principle and is likely to solve the problem of shortage of water at Bombay and Madras. It is estimated that Tarapore atomic power station will cost Rs 48 crores. An extra expenditure of 17 crores will give a desalination plant with a production capacity of 104 million gallons per day. Very high capacity of such plants will naturally make the use of these plants restricted to regions of very high requirement of water.

For every one million gallon per day of fresh water produced from seawater, the chemicals obtained are salt (NaCl), 205; magnesia, 16.10; potassium chloride, 5.42; calcium oxide, 4.28; and bromine, 0.5 tons. Such recovery of chemicals may be done either before desalination or after desalination. For example, magnesium may be recovered as magnesium ammonium phosphate (a good fertilizer) before desalination improving thereby the performance of the desalination plant. Although recovery of chemicals may improve the economics of desalination, such recovery plants will involve huge investment cost. It may therefore be quite reasonable to confine the recovery to more mostly by-products like bromine, for recovery of a quantity of which one has to treat less volume in case of discharge of desalination plant than from seawater. Bromine if recovered from discharge brine of desalination plant will bring about some profit to compensate cost of water.

Based on the above consideration and reasoning, feasibility studies are being carried out in the Institute with a view to determine the most economical and suitable process for obtaining fresh water from seawater at reasonable cost, and the necessary engineering data are being collected.

Seawater as Coolant

S. D. GOMKALE & R. L. DATTA
Central Salt & Marine Chemicals Research Institute
Bhavnagar

Seawater may be used as coolant in industries near sea coast; such use will save a large quantity of normal water which would otherwise be required to be cooled and recycled for further use in additional plants involving extra capital and operating costs. Nevertheless, due to the presence of 3.5 per cent of dissolved salts and organic matter in seawater, fouling, scaling and corrosion take place. These can be controlled by proper choice of materials of construction, cathodic protection, protective coatings, use of clarified seawater, limited chlorination, optimum coolant velocity and careful design of equipments with due consideration for the best transfer of heat in regard to all these aspects. With the help of the physical properties of seawater and other pertinent data, heat transfer coefficient can be calculated and used in the design.

Most of the chemical process industries involving heat transfer operations require large amount of water for cooling purpose. In water scarcity regions, a separate cooling system has to be taken recourse to in which the water is recycled with the required amount of make-up water and through cooling towers. Extra capital investment and higher recurring expenses are involved due to losses and pumping in cooling towers. A single cycle cooling is preferred where there is a continuous flow of water near the industry. Table 1 gives requirement of water for some chemical industries per ton of product.

Seawater can be used as coolant as it will not come in direct contact with processed and product materials. In case its direct use for cooling is prohibitive it can be used for cooling the normal water. Use of seawater for cooling is advantageous due to its availability in large quantity and less pumping cost and does not require elaborate cooling system. It contains about 3.5 per cent of dissolved salts, and also living organisms which bring in problems like fouling, scaling and corrosion in severe form. Of these corrosion is the most important.

Fouling is due to the suspended matter such as algae and other oily and organic matters in sea. It can occur at all points in the form of algal growth.

Table 1 — Water requirement for some chemical industries

Industry	Water requirement (gal./ton)	Industry	Water requirement (gal./ton)
Steel	65,000	Ammonia, synthetic	26,000
Sulphuric acid	3,000		
Soda ash	14,000	Oil refining	770*

* Requirement in gallons/Bbl.

Such growth reduces the carrying capacity of pipes and will reduce the heat transfer capacity also. Therefore seawater to be used as coolant must be as clean as possible. Adhering type of growth may prevent erosion to some extent due to higher velocities but simultaneously corrosion may start. Its removal of such growth from surface is possible by flushing with hot water or by steaming. Chlorination prevents algal growth. Intermittent chlorination with chlorine concentration of 1 p.p.m. is quite suitable and does not increase the corrosivity of seawater.

Scaling is due to dissolved salts in the seawater. These salts on account of their inverse solubilities crystallize out and deposit on heat transfer surface in the form of scale reducing thereby heat transfer. This is true of calcium and magnesium salts. The scale formed may serve as a protective film against corrosion. But this problem can be neglected in case of seawater cooling as higher temperatures are not attained.

Corrosion of seawater is due to dissolved salts and living organisms. Dissolved salts promote the acqueous corrosion in which electric current flows from anode to cathode and this effect is more than that of pure water. In case of steel, ferrous ions enter the solution at the anode and hydrogen is deposited at cathode resulting in corrosion of steel. Some of the salts like sodium chloride and ions like HCO_3, F, Br are highly corrosive. Effect of Br and F is less due to their lower concentrations in seawater. Dissolved oxygen promotes attack on metal by reacting with nascent hydrogen deposited on cathode.

The corrosion observed with seawater can be classified as galvanic corrosion, impingement corrosion, bacterial corrosion, dezincification, pitting etc. Galvanic corrosion is due to onset of current and is more severe in case of dissimilar metals. Thus in a condenser with steel head and cupro-nickel tubes, steel head will be anode with respect to tubes as cathode and corrosion will start. In impingement corrosion metals are corroded due to high coolant velocity and is observed to be more in case of copper and its alloys. The higher velocity is responsible for cavitation attack which occurs due to repeated pounding from rapid collapse of vapour bubbles. Dezincification occurs in case of copper-zinc alloys and takes place due to selective leaching of zinc leaving copper in porous form. In pitting local areas are corroded at higher rates and small holes and pits are formed.

In order to control these difficulties the following measures may be adopted : (a) choosing proper alloy, or better corrosion resistant metals, (b) cathodic protection, (c) using protective coatings, and (d) careful design.

Study indicates that most corrosion resistant metal and alloy are titanium and Hastelloy. Titanium and also Hastelloy are very costly. Hence use of alloys like cupro-nickel, aluminium, brass, monel, stainless steel etc. is very common.

In case of cathodic protection, an external sacrificial anode is used. This anode is dissolved and protects the equipment. Another way of cathodic protection is to pass a current from an external source on the equipment counter to the natural current. Magnesium, aluminium, zinc and certain other metals serve well as sacrificial anodes. Out of these magnesium is commonly used.

Further protection can be obtained by use of inhibitor which in small amounts in corrosive media give a protective film on cathode or anode preventing the onset of current. Many organic and inorganic coatings are available which will suppress corrosion.

In short, the following points must be carefully considered before using seawater as coolant : (i) material used in construction should be as close as possible to one another in the galvanic series to control galvanic corrosion, (ii) a small area of an anodic metal coupled to a large area of second cathodic metal is always dangerous; reverse proportion is satisfactory in service, and (iii) paintings for protection must be done for both the metals.

Apart from these measures one has to be very careful in design of equipments for seawater as coolant. Calculation of overall heat transfer coefficient must be done carefully using physical properties of seawater. Variations in inlet temperature of seawater will affect thermal performance of equipments and hence the seasonal variations in temperature must be accounted for in the designs. Selection of metals and means of its protection should be carefully thought of. But the most troublesome design factor is the inlet velocity which is the root cause of impingement, cavitation corrosion and pitting if the velocities are very high. Impingement effect is visual up to a length of about 15 cm. from the inlet and it has been observed that in many cases the metals are selected on the basis of inlet velocities. However, experience with seawater as coolant gives a value of 5 ft/sec. as critical design velocity though, as indicated in Table 2, some alloys can stand higher velocities. Turbulent flow must be maintained for better heat transfer.

Galvanic protection will also reduce the effect of higher velocity. Considering fabricational aspects one finds that flaring of tubes will definitely help in reducing this effect. The ratio of cross-over area in the head to total cross-section area of tubes be 1.25 :1.0. Also from standpoint of turbulence, side entry is preferred to axial entry at the front end of condenser. In fabrication of condensers and heat exchangers preference must be given to flange or welded joints with protection and threaded joints be avoided as far as possible.

Use of steel for outer bodies and cupro-nickel or aluminium-brass for tubes is very common. It is seen that all types of condensers, viz. surface, falling film and cascade type function vary well with seawater as coolant.

Normally pumps with cast iron body with little of nickel and bronze impellers are better. Butterfly valves with aluminium bronze flapper are better. For overhead service lines steel is better. For underground purposes cast iron or cement lined pipings are better. Plastic and PVC pipings are also suitable. It must not be forgotten that use of seawater will require duplicate piping system.

Overall arrangement for using seawater as coolant will include pump located away from polluted source and at a place where water is readily available with travelling or stationary screens to prevent flow of suspended matter (at the intake) in the piping. Chlorination will be done after delivery end of intake pump. Again as a safeguard all the equipments using seawater for cooling will be fitted with strainers in the inlet line.

Table 2 — Data on velocity

Material	Max. velocity (ft/sec.)	Material	Max. velocity (ft/sec.)
Admiralty brass	5	Cupro-nickel (90 : 10)	15
Aluminium brass	8	Cupro-nickel (70 : 30)	20

It is very necessary to use seawater for cooling purposes in industries near the sea-shore to avoid water problem. It is a good sign that effort is made by some industries in our country in this respect and their experience will induce others to use seawater as coolant. This institute can render assistance in this connection to the interested parties.

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Design of Process Equipments for Marine Chemicals

V. N. LELE, D. J. MEHTA & D. S. DATAR
Central Salt & Marine Chemicals Research Institute
Bhavnagar

Design of equipments for the recovery of chemicals from sea and inland brines has become one of the major activities of this Institute. Priority is given to design the draft tube type continuous extractor, flotation cell and continuous centrifuge. By introducing these continuous type of equipments in plant, it is expected to keep the capital outlay at lower level, minimize delays in operations and bring down the cost of recovery of potash fertilizers from marine bittern.

The development of processes for the recovery of chemicals from marine bittern has been gaining momentum in Indian industries. Special types of equipment are needed to design to fit the type of products to be processed and to bring them to industrial realization in the most efficient and economical manner. Keeping this object in view, the Institute has taken up the work on design of equipments specially required for the recovery of by-products from marine bittern. Priority is given for designing the equipments such as continuous extractor and conditioner, continuous centrifuge and flotation cell for the recovery of potash fertilizers from bittern which is the only indigenous source, at present. Continuous extractor is designed to extract potassium chloride as carnallite — a double salt of $KCl.\ MgCl_2.6H_2O$ from mixed salt — thereby large number of batch type extractors can be eliminated. The continuous extractor has been designed and fabricated in the Institute. It is based on the principle of draft tube mixers in which solid particles come into close contact with solvent for the pre-fixed retention time. Due to ideal solid-liquid contact it is also suitable as conditioner. Similarly, a suitable flotation cell is being designed for the recovery of potassium chloride in the form of kainite — a double salt of $KCl.\ MgSO_4.3H_2O$. Special care is needed to design the flotation cell so that desired size of bubbles can be maintained uniformly throughout the operation period of the cell for the maximum recovery of potassium salt. It is a known fact that the recovery of by-products from marine bittern involves the separation of solid and liquid from the slurry at each step. This involves the operation of dewatering by means of centrifuges. Large number of batch type centrifuges are required in the plant. This not only involves cost but also operational difficulties. To avoid this, a continuous centrifuge with vertical bowl and scraper is designed with a capacity to handle about ten tonnes of crystalline materials. By introducing a continuous extractor or conditioner, flotation cell and centrifuges, it is expected to bring down the cost of the potash fertilizer plants.

It is also proposed to take up the design work on vibratory feeders, slurry pumps, metering pumps, rotary and horizontal tipping filters, continuous crystallizer etc.

Continuous extractor

The concept of continuous processing and optimization has been firmly establised in the chemical process industries. In the field of marine chemicals plants such as for potash fertilizers, the important considerations in plant design aim at continuous processing with simple and effective units. The peculiar characteristics accompanying the extraction of low percentage of potassium chloride in mixed salt is kept in view, in this design.

Continuous dissolver therefore, is designed for effective mixing and extraction with proper retention time or hold-up for the reactants. Double pipe heat exchanger as liquor preheater, feed hopper and jet mixer for wetting mixed salt and introduction of slurry in the draft tube or core of the mixing zone are the auxiliary requirements. The dissolver comprises two equal partitioned tanks with common jacket for steam and a concentric tube in each tank. The vertical shaft has two stirrers, one at the bottom below the tube and other at the centre portion of the tube. Turbine type bottom stirrer and propeller type central stirrer rotate at 250 r.p.m. so as to cause the displaced mix by the bottom stirrer to rise, rotate and again coincide in the draft tube for recirculation. The draft tube is thus a sequential baffle. The stirrer within the tube maintains constant suction and the flow is passed downwards for cumulative mixing. The square size of the tank is useful to prevent the repetitive horizontal movement of slurry. The feed slurry is intimately mixed at the bottom of draft tube with the tank slurry of constant concentration.

In the unit fabricated in the Institute feed rate is 4.5 l./min. and the turnover of draft tubes is 410 l. The overflow from first draft tube enters the other draft tube where it is subjected to similar cycles of mixing. The extracted discharge liquor is taken out from the second tank as overflow. Kinetics of continuous extraction being known, exist liquor concentration can now be theoretically estimated for such stirred tank extractors of any capacity, when feed rates of streams are known. Higher capacity unit for this system would be a simple geometrical replica to suit the optimum production rates. It is designed on the principle of stirred tank mixer-reactors wherein perfect mixing is assumed.

This unit is applicable for almost all operations where intimate mixing of solids and liquids, with or without heating and cooling, in the slurry form for extraction or blending is essential. It is also useful as conditioning equipment for the purpose of flotation.

Flotation cell

The flotation process is a commonly used method for the recovery of potassium salts from potash bearing minerals. It is also found in the Institute to be relatively an efficient operation at low cost for the recovery of potassium fertilizers from mixed salt obtained by solar evaporation of bitterns.

The Institute has set up a flotation unit which consists of four cells each having a volume capacity of 78 litres and provided with diffuser, impeller and device for the supply of air under controlled conditions. Preconditioned pulp of mixed salt is charged into one of the cells of the flotation unit. The pulp and air mixture is diffused under intense pressure offered by the impeller so that a portion of the air is dissolved in liquid media used for flotation and the remaining air is divided into small bubbles by the sheering action of the pulp and air against the diffuser blades. When the pulp leaves the action zone of the impeller-diffuser area, the dissolved air precipi-

tates on the reagentized surfaces of the kainite or potassium chloride depending on the type of mixed salt subjected to flotation operation. The precipitated air together with finely divided bubbles lift the particles of kainite or potassium chloride through the separation zone to the surface as concentrated froth, and sodium chloride together with other impurities is discharged out as tailings from the bottom of the separation zone.

The optimum capacity of the existing flotation cell for processing mixed salt is established by operating the cell under various conditions like pulp density, flotation contact time, particle size and type and quantity of frothing agents used by proceeding 200 to 500 kg. of mixed salt. From these data capacity of a bigger cell to handle 20 tonnes of mixed salt per day is determined. The overall dimensions of individual cell, detailed design and working drawing of flotation cell are undertaken so that the unit can be fabricated indigenously for the beneficiation of mixed salt for the production of potash fertilizers.

Continuous centrifuge

Centrifugal separation is finding ever-increasing use in chemical processing. Though it is an established operation in the chemical industry, and fair descriptions of the various types of centrifuges in use abroad are available, there has not been made in India an attempt to design and fabricate a centrifuge suitable for a particular application.

In view of the requirement of continuous centrifuge for the various chemical plants of this Institute in simplifying the operations and bring down capital investment, survey of continuous centrifuges of different types was undertaken. Based on published articles and literature, manufacturers' data, performance reports of various machines, laboratory data and data on Indian batch type centrifuges, centrifuge suitable for continuous separation of free draining or crystalline materials is designed. Selection of a centrifuge for particular duty is itself a subject of number of investigations and serves as the guide line for design.

Amongst the major types of continuous centrifuges, applicability is particularly based on solid separation using perforated basket and imperforate basket. The centrifuging equipment available abroad can be classified into imperforate horizontal bowl and scraper, horizontal bowl and intermittent scraper, horizontal bowl and cyclic pusher discharge, and vertical bowl with vertical scraper. The last one selected for design has been reported to be extensively used for crystalline products such as common salt, potassium salts etc., in general for free draining of crystalline materials. Advantages are maximum output, possibility of drying the material up to 2 per cent moisture thus freeing the adhering liquor, low investment, unattended smooth operation with low labour cost and least wear and tear. Continuous centrifuge suitably designed to accommodate the solids separation is normally very useful in overall simplification of plants and bringing down the investment.

Basket and scraper at 1000 and 900 r.p.m. are rotated by V-belt and pulleys, mounted on common shaft. Basket size is 23 cm. top diam. and 46 cm. bottom diam. with 41 cm. slant height. Five H.P. motor is observed to be suitable. Output of this unit will be 173 kg./hr m.^{2} of basket which corresponds to about 10 tonnes per day. Liquor handling rate would be about 49 l./min. m.^{2}. Suitable hydrocyclone will be utilized in thickening the feed slurry to 50–60 per cent solids.

A centrifuge of this size would cost about Rs 3000 overall size being 1.2 m. × 0.9. m. × 0.9 m. × 1.2 m. weight of machine at about 750 kg., capacity to centrifuge crystals at 10 tonnes per day, a distinct difference from batch centrifuge.

The important design aspects of continuous centrifuge are feed slurry rate, liquor handling rate, solids cake thickness, r.p.m. of basket and scraper, centrifugal force (number) developed, nature of solids handled, top and bottom diam. and taper of the basket, drive H.P., initial and final moisture content of solids, shaft diameter and location of bearings. A twin pulley drive dispenses with conventional four gear assembly. There are about twenty parts of this centrifuge.

The fabrication of such type of continuous centrifuge is being taken up in Institute's workshop. It is expected that if so required, the design and fabrication of almost any other type of continuous centrifuge can now be taken up.

Design of Solar Still for Sea or Brackish Water Desalination

S. Y. AHMED, S. D. GOMKALE & R. L. DATTA
Central Salt & Marine Chemicals Research Institute
Bhavnagar

Although limited in scope, solar still technique of desalination has significance in a tropical country like India, particularly in certain isolated regions like salt works or islands where power or fuel is not available for the purpose, natural source of water is not existing nearby, and the transport cost of water is very high. Design and operational data of the 500 gal. capacity plant set up at Bhavnagar were used for obtaining actual investment cost per unit area of covered space, and to make a cost anaylsis by itemwise break up of the requirements. Such an analysis indicates that compactness of design, and better utilization of solar energy will improve economics of fresh water production.

Seawater contains 35,000 parts per million of dissolved salts. To reduce such salts to less than 500 parts per million, as recommended by World Health Organization for drinking water, a theoretical minimum of about 3 kWh. energy is necessary per 1000 gal. of fresh water, although in practice, many times more of this amount is required. Such high requirement of energy makes fresh water several times costlier than conventional water. Attempts are therefore made in the techniques of desalination to reduce actual requirement of energy, and also the cost of such energy. Hydroelectrical power, and also nuclear power which is estimated to cost 2.5 paise per kWh. will certainly reduce the cost of fresh water. Combination of desalination with power plants and recovery of costly byproducts like bromine which is present in seawater to the extent of 65 parts per million will improve economy of fresh water production. However, for a tropical country like India, with more than 2000 Btu. sq. ft per day of solar energy for a longer period of the year in certain regions, solar still technique has special significance. Also in certain salt farms of Kutch and Saurashtra regions (Gujarat), where the requirement of water is of the order of a few hundred to thousand gallons per day, the cost of water transport is very high varying from Rs 11 to Rs 42 per 1000 gal. of water, power or fuel is not available for the purpose, no other natural source of water supply is existing nearer than 15 miles, solar still technique of desalination is definitely useful. In some islands of India, there is possibility of development of such a technique. In water scarcity regions near seashore, the possibility of development of house top units of solar still exists.

Design

Keeping in view the need for comparatively small size unit in the country, a solar still plant of 500 gal./day capacity is designed and is being constructed

at the experimental salt farm of the Institute. The area which requires to be developed and covered by glass at 10°-10° (for Saurashtra and Kutch regions) for the 500 gal. capacity with only 30 per cent of solar energy being utilized, is 1/5 acre, having altogether 21 stills in the plant, 10 stills (55ft × 8ft) at an estimated capacity of 250 gal. per day is completed and is producing nearly that quantity of water daily. Concrete bottom of each still has black lining in which seawater gets evaporated by solar heat, transmitted through the glass cover. Condensate on the inner side of the glass trickles on to the canal provided for the fresh water and is collected in product water tank. In the design of the plant, provision is there for collection of rain-water also.

Cost analysis

Although simpler materials like glass, cement, bricks, sand, morrum, trap metal, paint, aluminium sheets, pipe and pipe fittings, pumps etc. are required for such a plant, the cost of investment is as high as about Rs 5 per square foot at present. Estimated cost of investment of the 500 gal. day plant is Rs 50,000, such high value being mostly due to the large space covered, and only less than 1/3 the solar energy being used. When the requirement of water is higher (20,000 gal./day), and in million gallons capacity, recently known humidification-dehumidification unit coupled with solar collector (this is being developed at the Institute) or flash distillation may be used, with less investment cost per 1000 gal. of fresh water, namely Rs 8260 and Rs 7850 respectively. Cost of fresh water by the solar plant is calculated to be Rs 8.45 per 1000 gal. Itemwise break up of the investment cost of the solar still plant shows that 65 per cent of the cost is for civil engineering materials and work, 25 per cent for other materials like glass, asphalt sealing materials etc. and 10 per cent is for labour. For improving economy in both investment cost and fresh water cost in this technique, therefore, it is necessary that civil engineering materials are reduced by making the design more compact and still cheaper materials like plastics with longer life are used. Use of soil stabilized bed instead of cement bed for the stills, and better utilization of solar energy (only 30 per cent is used at present) as in multi-reflection arrangement of the glass sheets, are likely to reduce overall investment cost and improve economy.

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Humidification-Dehumidification Technique for Seawater Desalination

S. K. GARG & R. L. DATTA
Central Salt & Marine Chemicals Research Institute
Bhavnagar

In the humidification-dehumidification (HD) technique of desalination of water, some of the limitations of solar still are removed with an overall decrease in the cost of fresh water. For example, space requirement is reduced to nearly 25 per cent and solar energy utilization is increased to more than 60 per cent as against 30 per cent for solar still, although some power, to the extent of 27 kWh. per 1000 gal. is required. From capacities of 20,000 gal. (below which solar still may be considered) to one million gallons per day or more, the HD units have possibility of development in India. In the investment cost of one million gallon capacity HD plant, 30 per cent 20 per cent and 10 per cent of the cost are for solar collector, condenser, and humidification tower respectively, which constitute major units in the plant. Indigenous materials only are required for construction of such a plant.

The solar still has limitations in its application both with respect to capacity of not more than a few thousand gallons of water per day, and high cost of investment. Our technological analysis shows that by better utilization of solar energy (at present only 30 per cent of solar energy is used in solar still) and making the design more compact, it may be possible to improve economy in regard to both costs of investment and of fresh water. These conclusions, namely, compactness in design, and better utilization of solar energy, are incorporated in the humidification-dehumidification unit coupled with solar collector. Space requirement compared to solar still plant is reduced to about 25 per cent. Although some small amount of power requirement is there (nearly 27 kWh. per 100 gal. water compared to 10 times this for flash distillation technique), about 60 per cent or more of solar energy is utilized. Principles of this technique are well established, and indigenous materials of construction are required for construction. There are possibilities that capacity as high as one million gallons per day or more may be established using the technique, although for lower capacities of 20,000 gal. per day or less, solar still, where applicable, may be preferred in regard to fresh water cost.

Design considerations and cost

The major units of the humidification-dehumidification plant are: (a) solar energy collector, which consists of stills containing seawater in which solar energy is trapped in to heat the brine to temperature of about 70°C.; provision exists in it for collection of rain-water also; (b) humidification tower wherein such heated brine is allowed to trickle through the packings of the tower countercurrent to air blown from its bottom; and (c) condenser

where condensation of vapour from vapour laden air stream from the tower takes places. Seawater is used as coolant, which is continuously streamed into the solar collector to conserve heat. Fresh water is collected in product water tank.

On account of reduction in space requirement to about 1/4, and utilization of solar energy to more than 60 per cent (compared to 30 per cent for solar stills) in the humidification-dehumidification plant, there is an overall decrease in the costs of investment and of fresh water. For example, for a 20,000 gal. per day capacity plant investment costs are estimated to be Rs 18 lakhs for solar still and Rs 4 lakhs for humidification-dehumidification plant. At various increasing capacities up to one million gallons per day capacity, costs of investment and of fresh water show exponential relationship. As for instance, investment cost of one million gallons plant is 20 times that of the plant of 20,000 gal. capacity, and the cost of fresh water is reduced by about 50 per cent in the former.

Major items of capital cost in a one million gallons plant are solar collector, condenser and humidification tower, constituting 30 per cent, 20 per cent and 10 per cent respectively of the total investment. Instruments will account for not more than 5 per cent. It is important to note that indigenous materials will be used for the entire construction of such a plant, the foreign exchange requirement (2–3 per cent of total investment) will be only for some instruments.

The necessary data for design of scale up units are being collected.

Acknowledgement

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Moulded Insulation from Magnesia and Calcium Silicate

H. V. SHAH & D. J. MEHTA
Central Salt & Marine Chemicals Research Institute
Bhavnagar

Taking advantage of the self-setting properties of magnesium carbonate trihydrate, a process has been developed for the preparation of moulded magnesia insulation from magnesia for application up to 300°C. The mould is prepared from 7.5 cm. length of a pipe steel. This pipe is jacketed from outside for circulation of hot water. In the centre of the mould a standard pipe is fixed by means of a flange in such a way that it can be operated easily. The outlet of the outer jacket is connected with one end of the central pipe by means of flexible pole. The inner wall of the mould and the outer surface of the central pipe are well polished for smooth operation and to avoid the surface irregularities in pipe sections.

Known quantities of wet cake of magnesium carbonate trihydrate are uniformly mixed with asbestos fibre in a double motion mixer. A calculated quantity of water is added to the slurry to absorb carbon dioxide liberated at the time of setting of the slurry in mould. Slurry is preheated and fed into the mould. Hot water at about 95°C. is introduced into the outer jacket, leaving the system through the outlet of the central pipe. This arrangement ensures even setting of the slurry in the mould. After fixed interval, the set pipe is injected out by means of a screw press. The set article is then dried in a drier at 110–20°C.

The effect of free moisture in the slurry, preheating temperature, time and temperature of setting of the slurry in mould are studied. The light weight (0.2 g./cc.) moulded pipe sections are obtained when the slurry contains 75–80 per cent free moisture, slurry is pre-heated to a temperature of 60°C. and setting time is 10 min. at 95°C. On the basis of data collected on a laboratory experiments, scale up experiments are carried out to prepare thirty pieces of standard length pipe sections in 8 hr.

From scale up experiments, a cycle time of 15 min. is established for preheating, filling, setting and injecting the moulded article. The steps of preheating, filling and injecting is worked out manually. Based on the data collected a machine is designed to inject out the moulded articles mechanically.

Calcium silicate insulation

Calcium silicate is also a thermal insulation material of increasing importance. In conventional process, the reaction between lime and silica sol is carried out at about 80°C. at atmospheric pressure under vigorous agitation. Mixture of centrifuged slurry and asbestos fibres is run into preheated mould and thereafter, heated under pressure up to 17 kg./cm.^{2} for about 20 hr. The mould is removed and dried.

The Institute has worked out a process for making insulation moulds in which the setting of moulded articles under pressure is eliminated and the operating cycle time is reduced up to the extent of 60 per cent.

Diluted lime slurry containing about 20 g. CaO/l. is charged into the jacketed reactor. Five per cent aluminium trichloride, on the total weight of lime and silica, is added in the reactor. The lime slurry is heated to boiling under continuous agitation. Silica sol containing about 75 g. SiO_2/l. is added at uniform rate. The slurry is centrifuged and cake is washed till free from chloride ion. The wet cake and 15 per cent asbestos fibre, on the weight of lime and silica, is mixed in a double motion mixer. The thick slurry is fed into the pipe moulds. Steam at about 1.7 kg./$cm.^2$ is introduced for 20 min. into the outer jacket of the mould. The set pipe is injected out by means of screw press. The finished mould is dried at 100°C. for 6 hr. The bulk density of the dried article is 0.2 g./cc., cycle time of 30 min. for filling, setting and injecting is established.

Applications

In moulded articles, generally the interlocking of hundreds of asbestos fibres from a positive heat seal which helps in eliminating heat losses at joints. Magnesia moulded insulation are used in insulation of steam pipes, ovens, boilers, locomotives, stills and in innumerable other applications up to 300°C. Calcium silicate moulded insulation are specially used for high pressure boilers, furnaces, high pressure steam lines and metallurgical furnaces up to 800°C.

Magnesia and calcium silicate insulation is rugged, durable that withstands even the most severe operations without crumbling and cracking. Moulded articles are easy to machine and fix up over the pipe lines and equipments in most tidy way.

Development of a Disperse Salt Washing Column

M. M. MOHIUDDIN, P. M. BHATT, R. K. SAPRE
R. L. DATTA & D. S. DATAR

Central Salt & Marine Chemicals Research Institute
Bhavnagar

In order to produce industrial grade salt from Kharaghoda salt a disperse salt washing column has been developed. It consists of a conical bottomed cylindrical column with stirrer from the top of which is fed continuously crushed salt countercurrent to saturated brine led in through its bottom section. Overflow pipe at its upper section carries away the impurities, and the washed salt slurry from the bottom is subjected to dewatering till the moisture content is reduced according to requirement.

Common salt produced from inland brine at Kharaghoda (Gujarat State) is largely different in physical characteristics from sea salt. It consists of crystal aggregates as big as 2–3 cm., and the colour of the salt is clayey due to lot of insoluble matter mixed up with it. The main impurities in it are calcium sulphate (1 to 1.7%), magnesium chloride (0.5 to 0.8 %), magnesium sulphate (0.1 to 0.2 %) and insolubles (0.6 to 1%), most of which are interspaced in the crystal aggregates of the salt. It is therefore necessary that such salt is to be crushed and subjected to the washing action of saturated brine in order to reduce the impurities such that calcium sulphate is less than 0.7 per cent, magnesium salts less than 0.5 per cent, and insolubles less than 0.5 per cent, as required by chemical industries. Finer salt cannot be treated in the conventional screw conveyor washery unit due to excessive slippage between salt slurry and the different parts of the washery unit. Consequently it is necessary to devise a technique by means of which such crushed finer salt can be washed.

Disperse salt washing column

The disperse salt washing column, which is designed for washing of such salt, consists of conical bottomed cylindrical column containing salt feed hopper and overflow pipe at the upper section, and brine inlet and salt slurry outlet at the lower section of the column. Crushed salt of sizes below — 16 BS sieve is fed to the column countercurrent to the saturated brine. Overflow brine carries away with it impurities, which are allowed to settle in a settling tank, and the brine is reused. The stirrer inside the column causes mixing and agitation of the salt brine mixture. The washed talt slurry is continuously removed from the bottom of the column, and led so the dewatering equipments for removal of moisture according to requirements. Salt obtaining after dewatering conforms to that required for chemical industry.

Dewatering equipments

Salt in the process of washing contains water to the extent of 40 to 50 per cent. Adhering nature of salt for water is accentuated by the presence of impurities like magnesium chloride. Dewatering equipments are, therefore, required to overcome such adhering forces also in order to get rid of reasonably high per cent of water part of the washed salt. This can generally be achieved by the application of certain established basic principles, namely (a) gravity force, (b) vibrational force, (c) pressure gradient, (d) centrifugal force, and (e) drying principle.

Basing on these principles, which can be applied either singly or in combination, the operations of use for the purpose are settling, decantation or draining, vibration or rotation in perforated equipment, filtration, centrifugation and drying. Use of one or more of the operations certainly is dependent on the moisture content of salt and the nature of use of washed salt (and corrosive action of salt). For example, salt slurry containing as high as 50 per cent water may be allowed to settle, and decanted or drained till the moisture content is reduced to nearly 10 per cent, when it can be fed to a centrifuge to reduce the moisture content to 3 to 4 per cent or less. Such a procedure may reduce the load on the centrifuge, but will certainly make the operation batchwise. Alternatively in a continuous operation, a set of vibrating screens may be used to reduce the moisture content of washed salt slurry to 10 per cent before feeding it to a continuous centrifuge operation, which can reduce the moisture content of salt lower than 3 per cent in certain types of centrifuge. Centrifugation further removes some amount of impurities like magnesium chloride along with water. Nevertheless depending on the nature of use of washed salt, selection of one or other of the dewatering equipments singly or in combination, may be made. For example, drying is required to be taken resort to for obtaining salt of 0.5 per cent or less moisture content. In a continuous operation, it is preferred that at later stage of centrifugation, the operation of drying may be adopted by blowing hot current of air through the salt while centrifuging.

Costs of investment and of washing

For a complete washery plant of capacity of 25 tons per hour consisting of roll crusher, belt conveyor, disperse washing column, clarifier and brine tanks, vibrating screen, pumps and motors, continuous centrifuge etc., the investment cost is estimated to be Rs 4 lakhs; and of this, about 10 per cent only is for the disperse washing column, and as high as 50 per cent for the centrifugal machine alone. The requirement of power for such plant is of the order of 170 H.P. of which 40 per cent is for crushing of salt alone, 30 per cent for centrifugal machine. Loss of salt during washing is of the order of 10 per cent and requirement of water is about 50 gal. per ton of salt.

Design of Salt Harvester and Mechanical Soil Stabilizer for Salt Works

R. P. DHIMAN
Central Salt & Marine Chemicals Research Institute
Bhavnagar

Mechanical salt harvester

The harvesting of salt, in India, is done by manual labour, using spades or showels. The salt manufacturing season is limited to seven or eight months in a year due to monsoons and other causes. The actual production period is even less due to the time required for harvesting of salt by manual labour and also due to the difficulty of getting the required casual labour for harvesting purposes. To eliminate these difficulties and to increase production of salt, it is necessary to mechanize the harvesting process to reduce the time for harvesting and utilizing the time thus saved for actual production of salt. Keeping this in view a Mechanical Salt Harvester has been designed at CSMCRI, Bhavnagar. The harvester has a capacity of 10 tonnes/hr, weighs four hundred kilograms and gives a pressure of about 0.7 kg. per sq. cm. It has an inclined blade which cuts a layer of salt as it moves forward and deposits the salt on to a moving conveyor belt from which it is chuted down into a van or trailer moving behind the harvester. The blade can be raised or lowered as required to suit the layer of salt to be cut by turning the wheel fitted beside the steering wheel in front of the driver's seat. The harvester is powered by a petrol/kerosene engine and is expected to be ready during the next year.

Mechanical soil stabilizer

The crystallizer pan is at present prepared by manually puddling the bed by using feet, in wet condition and levelling it later by moving a roller manually over it. This gives the soil a pearing strength just sufficient for harvesting salt manually.

For using mechanical salt harvester on the crystallizer beds greater bearing strength of the soil than manual harvesting is required. Work has been started on the design of a suitable Mechanical Soil Stabilizer weighing about two tonnes which will raise the bearing strength of the soil to about 3 kg./cm.^{2}. The details are being worked out.

Indigenous Design and Construction Facilities Available in India

M. T. SHAH
Indo-Berolina Industries Private Ltd
Bombay

The urgent need for producing the basic chemicals could be understood when we take into account that over Rs 500 crores worth of chemicals would have to be imported during the Fourth Plan to maintain the present rate of industrial development in the chemical industry and to maintain minimum standards of living for our increasing population.

With chemical technology developing fast, planners in a developing country must bear in mind a number of points before they make out a scheme for the development of chemical industry :

1. The potential market areas for various products
2. The proper utilization of all available raw materials
3. Minimum economic sizes for each unit
4. Location of the unit taking into consideration availability of raw materials, freight, availability of utilities, transportation facilities and consumption areas
5. Possibility of obsolescence of the process planned
6. Development of design organizations and making available of process know-how
7. Development of engineering organizations for detailed engineering and implementation of projects
8. Last, the importance of coordination of projects so that surplus raw materials from one industry is used to produce desirable end products without having time-lags in between

It is obvious that all these would demand a continuous study by talented engineers and technologists to minimize error of judgement.

The present practice in India has been to give contracts mostly to foreign companies. The tendency of these foreign companies is to maximize imported equipment with little regard to the indigenous manufacturing potential. This being the practice, the indigenous manufacturers are at a disadvantage on account of the following :

1. Engineering-design firms mostly in foreign country, have very little interest in the Indian manufacturing industry.
2. It is very difficult for foreign companies to select Indian equipment as the design standards sometime are different and they are not interested in supplying more information and more detailed drawings.

3. It is difficult for indigenous fabricators to get the desired clarifications regarding their drawings as most of the designs are made abroad.
4. Thus it is also difficult for the indigenous fabricators to give satisfactory delivery time schedule.
5. It is also almost impossible for the designs to be standardized particularly with reference to certain standard equipment, e.g. Heat Exchangers etc. This does not offer an Indian fabricator any direct incentive to have detailed mechanical engineering design facilities at his own shops.
6. These force the local fabricator to answer in the negative when queries are put forth.

It is obvious that to reduce the drain of foreign exchange on know-how cost India has to develop its own research and pilot plant facilities. This may take considerable time and money and it should be the responsibility of every major industry to have research and development department associated with them besides having national research laboratories etc.

If the know-how is not available in India it can be purchased from Western sources or from countries with whom rupee payment is possible. If the know-how is to be purchased from Western sources it may still be possible to purchase equipment from Eastern European countries.

The advantages of selecting an Indian engineering firm may be summarized as under :

1. Entrepreneur may buy equipment from Western sources or from Eastern European countries, based on the specifications submitted by the design-engineering company. In case of Indian firm there will not be any objection in following this practice. But, in the case of foreign engineering firms they are likely to be tied up in the purchase of equipment from their own block only.
2. Since all the detailed engineering will be done in India, saving in foreign exchange to that extent will be effected.
3. Design-engineering company will be able to maximize the use of indigenous fabrication facilities as they have no interest to import from outside.
4. The same firm can undertake construction supervision or total construction.
5. This means total engineering under one responsibility which is highly conducive for efficiency.
6. The problem of coordination of various establishments of the projects would be greatly simplified.
7. Time-schedule can thus be considerably improved.

There is a large group of people who continue to think that by entrusting the complete project to a single foreign firm the work will be done in good time and efficiently. If the firm is competent, it is quite likely that the job is completed in reasonable time and efficiently, but at a considerable increase in foreign exchange expenditure which could be otherwise saved, if the same is implemented by a competent Indian engineering firm.

Besides, when the equipment are to be imported considerable uncertainties exist with regard to delivery time as well as freight and because of all

these none of the projects taken in the last Plan has been completed in the original schedule. While some delays can be considered inevitable it is obvious that the engineering-construction company which can do design and engineering in India will be able to implement the project on a much better time schedule at the same time effecting considerable saving in foreign exchange. It is, therefore, imperative that the Government should press public sector undertakings as well as industrialists to ensure that design and engineering facilities established in India are utilized to the fullest possible extent. This is further substantiated by the experience of some other countries who have developed rapidly, e.g. in Japan for many years the licensing arrangements were to be approved by the Ministry of International Trade; and engineering and construction as well as procurement of equipment was done mostly by Japanese firms. Whenever it was not possible for Japanese firms to do the job independently they had formed collaborations with foreign firms to develop their own engineering ability.

Indian firms for fabricating chemical plant equipment have now developed fairly large capacities, but it is regrettable to note that almost all of them are operating below their rated capacity. This may directly be attributed to the fact that almost all the engineering of chemical plant installed in India during the last few years has been entrusted to foreign firms. This aspect has therefore to be reviewed in a comprehensive manner and project development work entrusted to Indian engineering construction firm utilizing maximum Indian know-how and equipment.

There are sufficient technical talent and design organizations in India today capable of taking up detailed design work; but unfortunately this fact seems to be not fully understood. It is gratifying to note that public sector industries at Sindri and Alwaye are planning their own design organizations. Recently a few consulting and design-engineering firms have already been established — some on their own and some others with foreign collaborations. It is now, therefore, possible to do complete detailed engineering and in some cases process engineering for various operations of petroleum refining, petrochemical processes, fertilizer manufacture and a large number of other chemical industries. These firms are also now quite competent to help entrepreneurs to advise in the selection of the best processes, to provide licensing arrangements as well as in the procurement of specialized equipment from abroad. They can also undertake detailed engineering, construction and construction supervision. Wherever the processes are new to India it is obvious that some difficulty would arise in convincing the entrepreneurs about the competency of the engineering firms. In such cases engineering firms with collaboration from recognized foreign engineering consultants can provide sufficient guarantee for the successful implementation of the project.

Any project to be implemented under our present emergency conditions should be based on the following points:

1. Process know-how should be purchased only after ensuring that indigenous know-how is not available.
2. As far as possible, all Indian projects — both in private and public sector — should see that the design-engineering companies selected are Indian, either wholly Indian or Indian companies with foreign collaboration.
3. Wherever possible process designing should be entrusted to engineering firms established in India, either wholly owned or with foriegn collaboration.

4. Detailed engineering should be completely done in India, based on rupee payment only.
5. Procurement of Indian equipment should be maximized on the basis of cooperation between designers as well as fabricators.
6. Procurement of foreign equipment should be on competitive international bids based on specifications supplied by the engineering firms in India.
7. Construction supervision and the entire construction should be completely by Indian firms.

If this procedure is followed for all major petrochemical and chemical projects like Gujarat complex, H.O.C. Project, fertilizer projects, petroleum refineries etc., considerable saving in foreign exchange will be ensured.

Need for Process Design Facilities for Chemical Plants in India

B. V. BHOOTA
Chemical Plant Manufacturers Association of India
Bombay

In the programmes of Development as envisaged in the Memorandum on the Fourth Five-Year Plan the target for Chemical Plant and Machinery has been set up at Rs 300 crores/year during 1970–71 compared to the estimated current production of Rs 90 crores per year. This means an addition of Rs 210 crores per year which would require that our production increases by about Rs 40 crores every year during the Fourth Five-Year Plan. This ambitious target — highly desirable and necessary though it is — is not easy to achieve unless certain measures are taken which would encourage the production of machinery for chemical plants in this country. It should also not be forgotten that, besides this Rs 210 crore/year addition for Chemical Plant Machinery, it is envisaged to add another Rs 200 crores for addition to Cement and Paper Machinery.

The targets set forth in the Fourth Five-Year Plan for production of nitrogenous and phosphatic fertilizers, heavy chemicals, petroleum refining and petrochemicals, cement, paper etc. can be solved only if we solve certain basic problems — the two most important of which are : (i) the need of design facilities in India and (ii) foreign exchange. Both are tied up to a great extent since if design facilities are available in India we could certainly reduce the foreign exchange requirements.

While considerable progress has been made in the local manufacture of sugar plants and to a good extent cement as well as paper plants, the situation with regard to the Chemical Plants, on the whole, leaves much to be desired. In case of fertilizer plants, acids and alkalies, petrochemical complexes and refining operations much more can be done in India if concentrated efforts are made in that direction. Most of these plants have come — and are still coming — on a turnkey basis and, for various reasons, very little use is made of local talent, both in design and manufacture.

In India today there exists considerable capacity — some of fairly high calibre — that can be used for manufacture of greater portions of equipment than has been done in the past. On the whole as is well recognized, our engineering workshops are not working at full capacity. They can manufacture some of the equipment being imported today provided they are helped by way of supply of necessary manufacturing drawings, together with specifications and given some assistance during manufacture where needed. If this is done, not only will we increase the workload and employment opportunities but also we would make the foreign exchange cover a wider field in that instead of one plant with most of the items imported we could have two or more plants with the same foreign exchange. The foreign supplier would also not be a loser since he is supplying the equipment

for the same value except only sophisticated items need be imported. It can be demonstrated that this would be advantageous to both parties in the long run.

The design and construction of chemical plants requires certain fundamental services as listed below, in entirety or in parts. These are to be properly planned, organized and coordinated for the economical and timely execution of the project. Some of the major functions which form part of the design and construction of a complete chemical plant are:

1. Know-how of the basic process; determination of the flowsheet. It should be the latest know-how, commercially proven and economically attractive
2. Plant design including the development of various stations in 'flowsheet' and sizes of major pieces of equipment in each station
3. Detailed designs and specifications of:
   - (i) Equipment items including material lists
   - (ii) Pipe lines, ducts and accessories etc.
   - (iii) Electrical equipment, including wiring layouts
   - (iv) Civil engineering drawings

   (It is assumed that ancillaries like water, power, waste, roads etc. will be taken care of separately. Otherwise these services should be taken care of here.)
4. Manufacture of the equipment and auxiliaries
5. Site preparation, civil works for the plant and ancillaries; facilities for personnel
6. Erection of the plant and machinery including interconnecting piping and wiring
7. Commissioning of the plant and training of the operating personnel

In the following paragraphs, an attempt has been made to review the availability in the country of the above requirements and steps to be taken to achieve self-sufficiency, to the extent possible, in the various functions.

Basic process know-how

During the three Five-Year Plans, especially during the last few years, India has gained considerable experience with the erection and operation of plants for the production of various basic and intermediate products in chemical and allied fields. These include caustic soda, chlorine chemicals, soda ash, sulphuric acid, nitrogenous and phosphatic fertilizers, sugar, paper and board, cement etc. For these plants, equipments in varying degrees have been manufactured.

There have come up some engineering design firms; also some engineering and development departments of processing industries themselves which could take up the design and supply of plants. While in the case of sulphuric acid, sugar, cement etc. the design is practically wholly being done in the country we in India are doing only some stations for other plants. In the case of nitrogenous fertilizers very little design facility is today available in the country. It can be said that where we have design capacity in India we are making more equipment in India and thus every attempt should be made to generate this design capacity in India. Where the country is lacking in the process know-how in certain specialized fields like, nitrogenous fertilizers, PVC, polyethylene, synthetic fibres, petrochemicals, organic chemicals and its various derivatives we should attract on terms

generally prevalent in international market, the foreign talent to fill in the gaps, so as to build up the necessary and sufficient design capacity in the country.

By participation with the foreign process know-how coupled with maximum utilization of indigenous resources it should be possible not only to do the design here but also the maximum amount of locally made equipment can then be used. The latter is generally not possible without the former. Once this is done considerable amount of foreign exchange can be saved. For accelerated industrial growth it might be even worthwhile not to limit the licence fees arbitrarily but to accept the generally accepted worldwide standards. Sooner or later, with the growth of experience in India, the engineering firms or industries operating in India would be able to improve or modify the process know-how to suit the Indian conditions and also possibly discover new or alternative processes by continuous research and development. Full scope should be given to the engineering firms established in India to develop the process know-how in the various fields. In fact, the collaborative efforts between Indian engineering firms, foreign firms who are willing to let their process know-how be used and the various national laboratories established in India, should result in a speedy change-over from dependence on external sources to self-sufficiency in this very important part of chemical plant design in India. In time to come thus it should be possible to 'export' the process know-how and equipment from India as it is now happening in case of Japan. The typical example is the process developed by FACT for reuse of gypsum in the phosphoric acid. Plant that is now ready for being exploited outside India.

Plant design

Once the basic flowsheet has been established, which could have necessitated laboratory or even pilot plant work, the next phase would be the design of various 'stations' comprising the flowsheet. The inter-relationships of various stations have to be properly fixed and the sizes of various pieces of equipment in each station need to be calculated.

Each 'station' in the flowsheet consists of equipment and the auxiliaries so that the station, as a whole, carries out a certain specified function. To illustrate, such a station could be a clarification, filtration, evaporation, heat recovery unit, rectifier station or a distillation plant. It is very seldom that one company can supply all the stations in a plant; one should generally go to a specialist firm for a particular station. Thus it is possible that if certain stations are available in India, i.e. designed and manufactured here, these could be separated out and supplied from here and integrated into the other stations coming from abroad. Every encouragement should be given to firms who can design such stations and supply from India as this would lessen the import contents and also give business in India. Even when complete stations are not available in India it is still possible to split up the engineering and equipment that a good percentage could be made here.

Generally the firm specializing in the design of the plant as a whole has to refer to specialists firms for the various stations. Therefore, in addition to the know-how for the process it is also necessary to make the country self-sufficient in the know-how of design of equipment and systems to perform specific unit operations like heat transfer, distillation, filtration, clarification etc.

Detail designs and specifications

Equipment. Once the sizes and specifications are determined together with the functions of each piece of equipment a detailed list would be available of items needed. It is possible that some of the items are available in the country which the designing firm may or may not be quite familiar with. In this context, it is very essential to compile a Directory listing the firms in the chemical field and the items of equipment they can supply so that any engineering firm can find out without much difficulty what items are available in India and what items need to be imported. The orders would then have to be placed with the various Indian and foreign vendors for these equipment and auxiliaries. The Chemical Plant Manufacturers Association of India should take up the preparation of such a directory as one of its most urgent and useful activity.

Pipelines, ducts, conveyers and accessories. Not only the equipment here is available from India but also the detailed designs could be easily done in India. Once the quantities of materials or liquids or gases to be handled are decided the design is not a difficult problem. Except for stainless steel pipes and rubber lined or plastic lined pipes of special sizes and some very special conveying systems most of the items could and should be procured from India.

Electrical equipment. The situation is about the same as for pipelines etc. above.

Civil engineering drawings. Sufficient talent exists in the country for these services and generally it is used also.

In view of the fact that indigenous talent exists in sufficient quantity it should be seen that for every new chemical plant this is used for design and procurement of pipelines, ducts, electrical equipment etc.

Manufacture of equipment and auxiliaries

A good deal of attention has so far been paid to the indigenous manufacture of equipment for chemical plants. Both in the public and private sectors large manufacturing establishments have been set up in the past few years. The necessary structural machine shops, forge and foundry facilities are available to an increasing extent from within the country. With the proposed increase in production of steel to 16.5 million tons, pig iron to 4 million tons, alloy steel to 500,000 tons, and aluminium 240,000 tons by 1970–71, the manufacturing industries could develop rapidly to meet the demand of chemical and metallurgical industries. So far the engineering industries have followed the growth of chemical and allied industries but still much remains to be done. In future they should be given higher priority and develop faster to take care of the needs of expansion of the chemical industry. By the end of the Fourth Five-Year Plan, a target of Rs 210 crores of chemical plant and machinery is expected to be reached. While at present manufacture of heavy equipment is possible within certain size and pressure limitations, facilities for manufacture of equipment of special materials of construction are still not available to the required extent. This is particularly so for stainless steel or special alloy equipment, rubber or other plastic-lined equipment, high pressure vessels, very large sized castings, etc. Complicated and precision made equipment, special gears, precision parts for instrumentation, specialized high speed bearings, are still to be imported and we have to make some considerable progress in the manufacture of these components. While the various shops in the country can manufacture equipment according to detailed drawings, a very

important lacuna in this field is the shortage of 'equipment design' facilities. For example, while it would be possible to get a heat exchanger or a crystallizer manufactured in India according to drawings, there are not enough specialized firms with Indian facilities who can undertake to do the design of these 'tailor-make' equipment for the various process requirements. Therefore, facilities for equipment design for the various unit operations have to be set up in the country at the earliest, if the machine building facilities in India are to be used most advantageously.

Civil construction

Here sufficient experience and talent is available from within the country and there is no reason to spend any foreign exchange for doing this work. Most of the chemical plants which have been put up in recent years have been constructed and erected by Indian firms and this valuable experience could be fully utilized for the various projects which are likely to be taken up in the coming years.

Erection of plant and equipment

Here too, as in above, sufficient talent exists but, in case of some specialized equipment, very little outside help may be needed.

Commissioning of the plant and personnel training

This aspect is partly connected with the process know-how. Till such time sufficient experience in new chemical process is acquired, it may be essential to get the help of foreign experienced specialists to commission the plants and train the operating personnel. This only applies to new processes where we still do not have enough experience. Once experience in operation has been acquired in these fields then the commissioning services could be carried out by Indian or foreign firms established in India, using the experience and talent of Indian Engineers.

Conclusion

From the above it would be seen that merely increasing machine building capacity in India is not going to solve the problem of building chemical plants. All the various ingredients which go to make up the chemical plants have to be made available from within the country in a progressive manner.

The equipment of various types and kinds would be required for any type of plant and this is particularly true of a chemical plant. In a typical flowsheet for, say, a sulphuric acid plant, the following sections will be basically involved:

1. Acid towers, tanks and heat exchangers
2. Waste heat boiler
3. Sulphur filter
4. Molten sulphur and acid circulating pumps
5. Main air blower
6. Acid proof bricks and packing
7. Piping and valves
8. Refractory materials
9. Insulating material
10. Instruments
11. Motors, starters and other electricals

The manufacturing equipment for each section can best be handled by a group specializing in that type of equipment. There will be plenty of ancillary requirements which the particular factory cannot handle or should not handle but can get done through others for putting the whole section together.

It would be better that encouragement was given to the production of certain type of equipment which is not confined to a particular industry but to a certain process function such as sedimentation, thickening, classification, rasting etc. Thus a thickener can be for sewage or sugar and a classifier for sand or for iron or gold ore. Thus it is difficult for any one shop to manufacture equipment for industries like fertilizer, refineries, petrochemicals etc. Actually what is required is engineering and design firms on the one hand, and specialized and general engineering shops manufacturing items like evaporators, compressors, heat exchangers, filters, pressure vessels etc. on the other. It is the engineering firm who would take up the responsibility of design, purchase of the various equipment from various shops and coordination, and would be in overall charge of every plant. The functions of a manufacturing shop would be responsible for the mechanical design of pieces of equipment. For overall plant design the engineering firm would be responsible.

Therefore, while it is very important to increase the manufacturing facilities in India, it is also essential to build up indigenous facilities for process know-how and design, equipment design and overall plant engineering. More Consulting and Design Engineering firms should also be set up not only to undertake techno-economic and feasibility studies but also act as main contractors for execution of projects. With a coordinated approach in which all these functions of project engineering would be interlocked the targets of the Chemical Industry in the coming years could be achieved with minimum foreign exchange requirements.

Chemical Plant Design and Construction in India

S. R. POTI
Kusum Products Ltd
Calcutta

This paper deals with the practical difficulties encountered by a firm of Chemical Plant Designers and Construction Engineers in trying to use technical know-how obtained in India, either by research or by practical experience in production factories, for the purpose of constructing chemical plants on an industrial scale and commercial basis. It will be realized that technical process know-how obtained by research work, or by any other means, can be of no use whatever unless a mechanism exists for converting such knowledge in a practical manner into actual industrial plants. This mechanism is nothing else but the operations of chemical plant design and construction firm. Therefore, this paper, will, we hope, be of interest to research workers and scientists also.

This paper does not deal with the fabrication of chemical process equipment. To government officers concerned with this engineering industry, 'Chemical Plant Design and Construction' is synonymous with 'fabrication of chemical process equipments'. But, 'Chemical Pant Design and Engineering' have nothing more in common with fabrication of equipments than with manufacture of pumps or electric motors. We have found it extremely difficult to make the concerned government officers to understand this point, which we think is due to a lack of understanding of the functions of a Chemical Plant Designer. As stated above, this paper outlines the experience and problems of a Chemical Plant Design and Engineering Firm.

The paper is the result of our experience in the design and construction of chemical plants in the last five years, during which period we completed and have under construction 17 chemical plants of small and medium size, such as glycerine recovery and distillation plants, alcohol plants, ethyl acetate plants, etc. We operate entirely with Indian technical know-how and Indian technicians only. The scope of our activities also includes:

(a) Acetaldehyde, Acetic Acid and Acetic Anhydride Plants

(b) Formaldehyde Plants

(c) Plasticizer Plants

(d) Fat Splitting and Fatty Acid Distillation Plants etc.

Given a little encouragement by the Government and the buyers of plants, we can rapidly expand our activities to many more lines and establish a large design organization, besides saving a lot of foreign exchange, and all this without any foreign collaboration.

Two types of chemical plant construction engineers

There are two methods in which complete chemical plants are constructed in India, namely :

A. By Indian fabricating firms collaborating with foreign design firms. In this case, there is a regular division of work, the foreign firm doing all the designing and detailing and the Indian firm merely fabricating, procuring and constructing.

In the early period of this collaboration, the foreign firm does part of the second function also, that is to supply some special items of the plant which cannot be made in India. But the ultimate object of this type of collaboration is for the Indian firm to do the complete function of procurement and construction, leaving the function of design entirely in the hands of the foreign firm.

B. By Indian chemical plant design firms doing the entire work of designing, procuring and constructing the plant. We belong to this category.

Needless to say, firms type (A) can never develop into design firms. Throughout the period of collaboration, they specialize only in fabrication and construction. They do not need chemical design engineers at all since they never do design, and even if they have chemical engineers, the latter never get the opportunity of designing.

If chemical plant design activity is to increase in India, it is to be expected from firms type (B) only.

Collaboration type (A) may reduce our foreign exchange requirements temporarily by procuring some items of chemical plants in India which otherwise would have to be imported, but this type of collaboration will keep our country technically dependent permanently on foreign countries.

Actual development of chemical plant design achieved in India up-to-date

If we take design of chemical plants as different from fabrication and installation, and it is right to do so, it will be seen that very little is being done in India now. As far as we know, on a commercial scale only a few types of chemical plants are being designed in India; namely

(a) Sulphuric Acid and Superphosphate Plants
(b) Alcohol Plants
(c) Oil Processing Plants
(d) Solvent Oil Extraction Plants
(e) Glycerine Recovery and Distillation Plants
(f) Some minor Organic Chemical Plants

To the above, we ourselves have added a few more lines recently, viz. (i) Fat Splitting and Fatty Acid Distillation Plants, (ii) Formaldehyde Plants, (iii) Plasticizer Plants, and (iv) Acetic Acid and Acetic Anhydride Plants, but we are yet to get orders and put our knowledge to practical use.

It may be that there are a few more small size chemical plants being designed in India, but they do not make a significant difference to the situation.

Recently, Engineers of Sindri Fertilizer Factory, started designing Fertilizer Plants and constructed an Ammonium Nitrate Plant in Rourkela,

but for reasons known better to our Government, this activity has been stopped now.

All other chemical plants constructed in India are either under collaboration type (A) or completely imported, so that no design of the plants is done in India.

Further, it will be noted that most of the types of chemical plants now being designed in India were being designed in this country during the second world war time. Two decades of industrial activity in Independent India, has not made us advance even one step in the line of chemical plant design while other lines of activities have developed considerably.

Only a very few firms, like D.C.M. Chemical Works and ourselves have attempted to design new types of plants, D.C.M. in the inorganic chemical field and we in the organic chemical line. We do not know what D.C.M.'s experience is, but from the rate of growth of their design activities, we cannot say that it is very happy. We ourselves find conditions in India extremely discouraging for the growth of chemical plant design activity.

If a rapid growth of chemical plant design activity is to be encouraged, it is necessary to face the fact that 18 years of independence has not given any impetus to this line of work, find out the reasons for it and remove them. It is the purpose of this paper to point out the main obstacles to growth of chemical plant design work and suggest some methods of removing these obstacles.

Factors favourable to growth of chemical plant design activity in India

1. Our technicians, including chemical and mechanical engineers, draughtsmen, etc. have a genius for creative work, such as Chemical Plant Design, even to a greater extent than in foreign countries. Our men only require the opportunity of being put on the jobs and given responsibility.

This factor is very important and should be fully realized by all who are really interested in the growth of chemical plant design activity in India. It is the lack of confidence in the ability of the Indian Technician which is the basic psychological reason for the craze for foreign designed plants both by our industrialists and our government officers.

2. Our fabricating workshops and manufacturing works for special machines like pumps, compressors, motors, etc. have developed very fast during the last decade, so that over 90 per cent of the chemical plant components can now be procured in India. This makes the situation easy for the Chemical Plant Designer. Design in India would have no meaning if procurement of most of the machineries is to be made in foreign countries.

Factors unfavourable to growth of chemical plant design activity in India

1. While lip service is being paid to the principle that Indian made goods and plants should be used wherever possible to substitute foreign made goods and plants, there is scarcely anyone in this country who does not prefer an imported thing to an Indian made article. The natural desire is to import and to prevent the evil effects of this, Government restrictions become necessary.

If a loop-hole is provided for importing a foreign made chemical plant in preference to an Indian made plant, anyone will try to pass through the loop-hole.

2. There are many real commercial advantages to the buyer in importing a chemical plant. They include:

(i) Lower price of the foreign made plant, particularly if the raw materials of construction such as stainless steel, copper, etc. are not made in India. Heavy import duty on raw materials, scarcity of materials in India and consequent high prices due to the activites of traders, all go to increase the cost of Indian made plant. Further, in most foreign countries export incentives are given and hence the prices of articles and plants exported to India may be lower than the prices of the same in the exporting country.

The price of a foreign made plant, including import duty, will be definitely lower than the price of an Indian made plant of equal specification.

(ii) Since Chemical Plant Design is only in its infancy in India, the technique of the best Indian designed plant is quite likely to be inferior to the best technique developed in more advanced countries. This situation will continue as long as design is not attempted in India and the above said technical collaboration with foreign designers will only perpetuate this state of affairs. Therefore, the buyer of an imported plant, if he selects judiciously, may get a plant with a more modern technique than a plant designed in India.

(iii) There are also other advantages in obtaining foreign exchange to import plants, which unscrupulous buyers exploit. These are well known to all and need not be detailed here.

3. Many buyers of chemical plants are technically incompetent and prosper not on account of technical competence, but due to scarcity conditions in India and their special ability to make use of these conditions. Such buyers, and they are many, are unable to distinguish between genuine chemical plant designers and cheap suppliers of chemical plants. These buyers have an implicit faith in foreign made plants, but are unable to distinguish the relative technical merits of a well-designed plant over an ill-designed but cheap plant. This has made possible the growth of so many mushroom designers in certain lines of chemical plants where import is totally banned. The bad performance of the plants designed by such parties increase the buyer's respect for foreign made plants, with very adverse consequences on such Indian firms who attempt to design plants in a scientific way.

Suggestions to increase and improve chemical plant design services in India

It is useless to expect buyers of chemical plants to throw away all the above advantages of importing plants and to prefer Indian made plants for patriotic considerations only. There should be some substantial positive benefit to the buyers who go in for Indian plants as against those who import.

Similarly, it is useless to expect an Indian fabricating firm collaborating with a foreign design firm to organize their own design department. They will find it much more economical to leave that function to the foreign designer. Hence, positive inducements of a substantial nature

should be given to the Indian collaborator to terminate the collaboration arrangement as soon as possible.

What these benefits should be for the buyers who take national interests also into consideration, is left for the Government to decide. But they should be substantial to override the benefits derived by the buyer in importing a plant. Such an inducement will not compel buyers to buy plant from Indian design firms on whom they have no confidence, but at the same time the buyer who favours Indian design is encouraged in the only effective way, that is financially.

We ourselves are in a position to design many types of plants which are now being imported such as fat splitting and fatty acid distillation plants, glycerine distillation plants, ethyl and butyl acetate plants, plasticizer plants, formaldehyde plants, acetaldehyde, acetic acid and acetic anhydride plants etc. We give guarantees of performance and none of the 17 plants we have constructed so far have given unsatisfactory performance. In fact most of our clients know that we can deliver the goods properly. But there are definite advantages in importing plants and buyers will continue to press the Government until they get import licence and they know that sooner or later they will succeed. Such conditions are not conducive to the growth of Chemical Plant Design Organizations in India and unless these conditions are altered, the next decade will not show any more advance than the past two decades have done.

Alkaline Manganese Dioxide Wet Cells

M. A. V. DEVANATHAN, N. RAMASWAMY & S. VENKATESAN
Central Electrochemical Research Institute
Karaikudi

Wet cells of the alkaline type using manganese dioxide as depolarizer have been developed. The system has the following advantages over the existing Leclanche cell system :

1. Only Indian manganese dioxide is necessary for these cells. This directly avoids the import of ores.

2. A new design of the cathode has obviated the necessity of using carbon rod as collector and the cell is capable of delivering heavy currents.

3. The cell has open cell voltage of 1.45 to 1.5 V. and the same operating range as the conventional Leclanche wet cells of the sac type. But this cell is capable of giving continuous heavy currents, i.e. cells of 500 A.H. capacity with 5 A. or 10 A. continuous drain can be readily fabricated.

4. The utilization of active material is very high, approaching the theoretical even at high drain.

5. Due to the new design of the electrode, the process of manufacture of these cathode elements does not involve any import of complicated machinery. Hydraulic press, mixers, ball mills etc. are readily available in India.

These cells are ideally suited for signalling, telephone exchanges, community radio sets etc.

Know-how for the production of such wet cells up to 500 A.H. capacity of any desired drain is ready.

Some Aspects of Research on Batteries and their Production

H. V. K. UDUPA
Central Electrochemical Research Institute
Karaikudi

The demand for batteries, both primary and secondary, is something phenomenal, and nearly 600,000 lead-acid batteries were produced in the year 1963 in India. It is a matter to be proud of that the country has well developed lead-acid storage battery industry. Much of this success is really to be attributed to the pioneering entreprenuers of Bengal who carried on production in spite of severe competition from imported batteries in the initial stages. As a result of protection given by the Tariff Commission, the industry has been able to establish itself on a secure footing so as to meet the pressing demands of the motor vehicle industry. Today the industry is capable of meeting the requirements of other purposes as well, such as that of the railways, aircrafts, traction, motor cycle industry and miner's cap lamps.

Testing of lead-acid batteries

It is but natural that with the industry so well established that the research activities of the Institute were directed mainly towards creating enough facilities for testing the motor vehicle batteries as there were hardly any testing centre in the country. By doing this, it was possible to be of service to the industry as the products manufactured could be evaluated by carrying out the tests as per IS specification. The testing facilities were expanded a great deal in order to help the Indian Standards Institution in their Certification Marks Scheme for the batteries manufactured. It was envisaged that the tests and analysis carried out would be of great help in the research and technological work expected to be taken up in the Institute.

Researches relating to lead-acid batteries

A few of the investigations which were carried out could now be considered here. The importance of particle size of the lead oxides used in the making of pasted plates was studied with a view to see the effects on capacity. In this connection, the influence of the acid added in paste formulation was also studied. This acid addition step could influence plate hardness, as well as formation characteristics of the plates was anticipated. In the matter of formation of charging, constant current and constant voltage methods were tried[1]. It was established that the latter method gave fine-grained lead dioxide as a result of which better capacity was obtained. Preliminary work has been carried out on the corrosion of grid under the above two conditions of charging. Although the definite advantage of adding lead dioxide has not been established, incorporation of the same in the positive plate formulation was found to be possible. Similarly,

inclusion of organic additives in the negative plate formulation to improve the low temperature performance of batteries has yielded encouraging results. Inclusion of carbon in the positive plate equally has indicated advantages in the performance at low temperatures[2]. The characteristics of the commercially available separators have been studied and a procedure of accelerated test for the life of these worked out[3]. This has led to the finding out of a possible way shoring occurred in batteries by filaments of lead formed by reduction of the lead sulphate deposited inside the pores of separators due to changes in sulphuric acid concentration during charge and discharge.

Here it is necessary to refer also to the processes worked out for the recovery of lead and antimony from the battery waste materials[4, 5].

The use of nitric acid or nitrate in the formation of Plante plate to be used in stationary batteries was investigated[6]. It was established that plates conforming to IS Specification could be easily made using this addition agent even at room temperature which is a decided advantage over perchlorate which should be used only at low temperature.

Fabrication of sintered plate nickel-cadmium batteries

Problems to be solved by using storage batteries have been considerably modified by recent electrical and electronic developments. It is difficult to meet these problems with lead-acid batteries alone. But electrodes for a sintered nickel base allow batteries to be produced which meet some of these latest requirements. The making of such batteries in the light of their details of construction and electrical properties, has been taken up with a view to examine from the angle of their production to meet the type of problems now faced. Nickel-cadmium batteries using thin sintered plates can meet with success in various types of applications, particularly as aircraft batteries. In modern times, the development of sintered plate nickel-cadmium batteries has been greeted as a development of the highest technical importance in the field of storage batteries in general.

Therefore, work on sintered plate nickel-cadmium batteries was taken up[7, 8] and the results obtained so far indicate the possibility of developing the complete know-how for the same indigenously. The electrochemical aspect of the problem has been fairly well known and the main problems which are required to be overcome appear to be centred on engineerring aspects of the fabrication etc. By the use of thin electrodes in the batteries, it should be possible to use such batteries at very low temperature also. Sintered plate nickel-cadmium batteries fitted for industrial use were not produced until about 1950 and considerable defects of negative electrodes and separators were experienced initially. High discharge results of these batteries were superior to those of the best lead-acid batteries. This is mainly due to the unpredicted decrease of internal resistance of these alkaline storage batteries. Some of the advantages for these batteries could be mentioned at this stage.

The capacity of the lead-acid battery considerably varies with the discharge rate but that the voltage keeps at an admissible value even for very high discharge rates. On the contrary, the voltage of the pocket type nickel-cadmium battery and chiefly that of the nickel-iron battery with tubular positive plates considerably vary as a function of the discharge rate, while the capacity does not vary very much. In the battery with thin sintered plates, neither capacity nor the voltage at the terminals are strangely affected by the high discharge rate. The amp.-hr efficiency of the cells with the sintered plate is excellent. The internal resistance of a sintered plate

nickel-cadmium battery is about 3 times smaller than that of a corresponding lead-acid starting battery and its discharge time at high rate is the same for the same discharge voltage as that of a lead-acid battery with a three times larger capacity. The lead-acid battery can therefore be replaced by a sintered plate nickel-cadmium battery with a third of this normal capacity without any risk. At least 4 to 5 different types of cells have been so far fabricated and tested. Although the test results have not been statistically analysed, successful results have been obtained with some of them even up to — 40°C. A large proportions of modern applications require high power batteries and these batteries appear thus highly fitted for such applications. From the economic point of view, it is to be mentioned that besides the high cost of the active material for the alkaline batteries, the cost of the sintered nickel support is higher than that of punched strip pockets or tubes of the conventional types. Naturally, the sintered plate nickel-cadmium batteries will be priced higher than the conventional alkaline types. It would of course be necessary to point out that the choice of the users will no doubt be influenced by economic consideration, taking into account the value of performance and the length of life.

Leclanche type primary cells

Leclanche type batteries are very well known as reliable sources of primary electric power. Researches are going on all over the world to improve upon the basic work carried out more than a century ago. The constituents of the cells are common and occur widely in nature. India being fairly rich in manganese ores, it is but natural that we should carry out investigation on the possibilities of using indigenous ores in battery manufacture. Further, more than 8000 to 10,000 tons of ores suitable for battery purposes are being imported into the country on the basis that the indigenous ore is unsuitable for the purpose. Preliminary investigations conducted in this Institute using high grade Indian ores (MnO_2 85% and above) have indicated the possibility of using these in the making of dry cells to give performance comparable with those marketed in India by well-known manufacturers in the country. So far as the investigation was concerned, the only aspect which required to be looked into in great detail appeared to be the constructional aspects of the dry cell. Naturally, cells were fabricated and then tested and the results compared with those obtained from the commercial cells available in the market[9]. The individual commercial cells, when discharged through 4.5 ohms to a cut off voltage of 0.8V. gave an average discharge time of 5 hr, the time required to reach 1V. being about 3 hr. The cells fabricated in this Institute using Indian ores gave similarly a discharge time of 5 hr, but the time to reach 1V. was found to be about 3.5 hr.

In the matter of fabrication of wet cells, it was interesting to note that prototype sac elements (S1) made by using Indian ores could give about 1.5 times the expected performances as required in the IS specification. The IS specification expects a performance of 1440 hr to a voltage of 0.75 as against which the performance obtained with the cells made here was 2200 hr. The same sac elements when used in alkaline electrolyte[10] could give a discharge time of 3000 hr. The voltage during discharge was always higher than in the cell using ammonium chloride electrolyte.

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Light-Weight Portable High-Energy Silver Batteries

PREM BEHARI MATHUR, N. KARUPPANNAN
& R. BALASUBRAMANIAN

Central Electrochemical Research Institute, Karaikudi

Silver oxide-zinc battery which is known as highest power density system has been discussed along with the other two high power battery systems, viz. silver oxide-cadmium and silver chloride-magnesium. Various specific applications based on their special features have been described in this paper. Some details of these three battery systems which have also been developed in this country at the Central Electrochemical Research Institute have been described and their requirements for the defence of the country have been indicated.

Introduction

Advanced during the last two decades in the fields of electronics, solid state physics, space and armament technologies have rendered it impossible for a country to fight out a war on ground, water, air or space without the aid of modern sophisticated weapons. With the development of modern communication system, the guided missiles, supersonic jet aircraft etc., the depth of the sea, the high altitude of mountains, the roughness of weather etc., do not stand as barriers in the present day wars. Defence poses to the country multitudes of scientific and technological problems. Innumerable items of varied nature needed these days for the defence have to satisfy extraordinary stringent conditions of weather and abnormal environments. Most of the commonly manufactured items suitable for civilian use do not stand the specific requirements of defence. The authors are discussing here one such item, viz. portable power system which is indispensable in a large numbe of defence equipments.

The modern developments in war technology have created newer and more exacting demands of the portable power supply for the infantry, submarine, ships, air force, missiles and space weapons. These requirements cannot be met with the conventional primary and secondary batteries. The more and more power in smaller units, ragged performance under the variety of environmental conditions such as extreme low temperature etc., fast activation, remote control and great reliability are some of the specific requirements of the newer battery systems in demand for the defence equipments.

Since the light weight and small volume of the power source like those of the other equipments carried by soldiers or guided weapons or the transport carriers is of immense importance, developments of high energy batteries which are capable of delivering the highest power per unit weight and volume have come into being after the second world war. Silver batteries, viz. silver oxide-zinc, silver oxide-cadmium, and silver chloride-magnesium

are known today as the most compact battery systems possessing highest energy per unit weight and volume.

The know-how of these three battery systems have been explored and the batteries have been developed in this country at Central Electrochemical Research Institute to meet the defence needs of this country. The various applications and commercial aspects of these high power systems have been described in this paper.

Silver-zinc and silver-cadmium batteries

In Table 1, some of the important features of the high energy silver batteries have been compared with the other commercial batteries available these days in the market. These high energy silver battery systems, as may be seen from Table 1, excel other battery systems in their capacity per unit weight and volume (about 4 times larger than those of the other batteries) and also in their flat discharge characteristics, low resistance and high discharge rate, fast activation and their performance over a wider range of temperatures. These special features of silver batteries have rendered them highly suitable for several newer requirements which cannot be met by the other systems.

Because of the very low internal resistance of the order of 0.0025 to 0.003 ohms the silver oxide-zinc and cadmium cells can be discharged at extremely high rates such as 3 to 4 min. rates (a 20 AH capacity cell at a rate of 200 to 220 amp.). On discharge these two cell systems deliver 70 per cent of the capacity at almost a constant voltage showing flat discharge characteristics at low as well as high rates of discharge. On storage in dry condition these cells show very long storage life since the elements of the cell systems are not deteriorated with time. These cells operate under high pressures and give good performance of low temperatures as may be noted from Table 1. Evidently the silver oxide-zinc and silver-cadmium systems are unsubstitutable where high energy density per unit volume or weight is an important criterion or very high rate of discharge with flat discharge characteristics or high capacity and good performance at sub-zero temperatures etc., are the specific needs for operating electronic equipments or for heating or lighting purposes in the remote cold regions.

The above mentioned qualities of the silver-zinc and silver-cadmium maximum energy density systems have opened a wide area of their applications during last decade[1]. These days these batteries are being used in all the advanced countries in large number of electronic equipments, such

Table 1 — Characteristics of various commercial batteries

	Working voltage	Capacity		Operating temp. °C.	Rate of current drain
		Whr/lb.	Whr/cu. in.		
1. Silver chloride-magnesium activated	1.30-1.60	10-70	0.70-5.00	—50-200	Medium
2. Silver oxide-zinc secondary	1.30-1.55	50-55	3.10-3.60	—20-165	High
3. Silver oxide-cadmium secondary	0.80-1.10	22-33	2.70	—20-165	High
4. Nickel-cadmium secondary	1.00-1.30	10-12	0.75-0.95	—60-150	High
5. Lead-acid secondary	1.95-2.05	16-20	1.50-2.10	0	
6. Mercury oxide-zinc alkaline	1.30	52-60	8.32	40-150	Low
7. Commercial Leclanche cell	1.25	30-40	1.60	30-90	Low

as portable communication instruments, infra-red detecting instruments, in missiles, satellites, jet aircrafts, helicopters, submarines, torpedoes,, emergency power supply, cameras, photo equipments, auxiliary heated garments etc. In a big country like India possessing the potentiality of developing all these military equipments, tools and appliances indigenously silver-zinc and silver-cadmium batteries production within the country will be of great service to the country.

Electronics Research and Development Establishment, Bangalore has introduced a silver oxide-zinc battery consisting eight numbers of 20AH, 1/2.5V. cells in XVM50 ground-to-air communication equipment[2]. This equipment alone may require 4000 to 5000 batteries in near future. Since each battery consists of 8 cells 32,000 to 40,000 silver-zinc cells of 20 amp. hr capacity may be needed for this single equipment. This may involve a foreign exchange to the tune of Rs 32 to 40 lakhs.

During recent years auxiliary heating devices to keep up the individual in heat balance have been developed in various advanced countries to overcome the problems of extreme cold weather faced by the soldiers at high altitudes and in low temperature regions[3]. Defence Textile and Clothing Inspectorate, Kanpur is also working on the development of such auxiliary heated gloves, socks, boots and complete body garments for use by our military personnel in extreme cold region of Himalaya. Research and investigations in United States of America and other countries have shown that nearly 120 watt hours are required to provide sufficient heat to warm up the extremities of the human body, viz. the two hands and the two feet, for 8 hr duration. Secondary silver cells have alone been recommended for the purpose and 6 to 7 pounds weight of the battery system has been considered to be maximum limit. Silver-zinc battery as well as silver-cadmium battery can give the required energy for a duration of eight hours within the specified weight. Since the number of soldiers posted in the cold regions of the country may be very large, the number of 20AH silver oxide-zinc battery consisting of six cells and capable of delivering the required power for heating up the handwear and footwear will also be very large. If a figure of 10,000 batteries is considered as the requirement for this specific purpose, 60,000 cells will involve nearly sixty lakhs rupees of foreign exchange if purchased from a foreign country.

Electronics and Research Establishment, Dehra Dun is understood to be developing an infrared equipment which can be attached to guns for detecting the enemy in dark. As in other cases the weight and volume of the battery which can operate the instrument is of paramount importance. Silver-zinc or silver-cadmium (20AH capacity) cells alone are considered most suitable battery systems to be used in the equipment. Here also depending upon the number of guns used in the war front the number of batteries will be required. The requirement of the single cells cannot be less than several ten thousands.

Another defence research and development establishment in Hyderabad has also shown keen interest in making use of 20AH silver-zinc secondary battery in some of their equipments. The future requirements of the battery by this organization has yet to be examined. However, it can be expected that this organization too would need a large number of cells for their equipment under development.

Bharat Electronics, Bangalore have developed walkie-talkie equipment to be used for civilian purposes by police department. Silver oxide-zinc 20 AH cell batteries are being used in this instrument.

Table 2—Specifications of silver-zinc secondary cell fabricated at CECRI

Weight of the cell: unactivated	330 g.
activated	400 g.
Dimension of the battery	5 cm. × 10.5 cm. × 4.3 cm.
Capacity	25 AH (at 5 hr rate and below)
Short circuit current	200 amp.
Low temp. performance	50% and more of the capacity at temp. up to —20°C.
Internal resistance of the cell	0.0025 to 0.003 ohms.
Improvement in capacity	25% higher capacity over the commercial cells

NOTE—The cells have been fabricated in same size polysterian containers which have been used for 20AH rated commercial secondary battery. Cells in other sizes and capacities can be fabricated on request.

This institute is also working on the activated type of silver oxide-zinc cells required for missiles by one of the defence organizations of the country. The highest energy, density, short activation time possessed by silver-zinc cells and the capability of the latter to discharge at very high rate made this system useful for use in guided missiles. The number of power pack needed for the purpose can easily be assessed to be very large.

With the modernization of our equipments, various other applications of silver-zinc and silver-cadmium batteries, viz. their use in high speed aircraft helicopters etc., will also emerge.

Considering the vast scope of their utilization in large number of defence and civilian equipments it is high time that the country should launch upon their production from the indigenous know-how which has been perfected by the Central Electrochemical Research Institute. We have not only been able to produce silver-zinc cells which are giving the capacities comparable with the commercial cells but we have been able to attain nearly 25 per cent more capacity within the specified volume of the so-called 20 AH rated cells. Some of the data on the silver-zinc cells developed at this Institute are given in Table 2. The 20 AH secondary cells which are being produced by us are expected to satisfy the present requirement of various defence organizations. The cells in other sizes and capacities can be fabricated on request.

Silver chloride-magnesium batteries

This system of battery has been found useful for severe services[4–6]. This system is being used in sonobuoys, pingers, torpedoes, weather forecasting, oceanographic equipment etc. In dry state the battery system possesses very long life. This system also gives very high ampere hour and watt hour capacities per unit weight and volume as may be seen from Table 1. Since it can conveniently be activated by seawater and be used immediately the system is being widely used in defence marine equipments. The Naval Defence Department of the country is keenly interested in the development and indigenous production of the system. We have already explored the know-how of this system and have perfected its developmental work. The production of the system can be taken up in the country in near future. The battery system which is developed for defence in the first instance is 5AH, 1.4V system.

With the perfection of the investigations and development work on these three high power battery systems the indigenous production of these batteries

will not only save in future a foreign exchange to the tune of crores of rupees per year but will develop self-sufficiency in these strategic items.

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Research and Development for Import Substitution in Electrical Industry

K. C. LALL & S. SWAYAMBU
Heavy Electricals Ltd
Bhopal

The manufacture of heavy electrical equipment has brought about a host of requirements for materials and processes to stringent specifications and components which require a high degree of skill and precision workmanship, not hitherto made in India on the large scale now projected. Although some success has been achieved in substituting indigenous supplies for the items manufactured so far, large scale independence from imports on the whole range of heavy electrical equipment, cannot be achieved without carrying out exhaustive investigations on the properties of the materials used and other aspects special to this category of equipment.

This paper describes the progress made so far in indigenous substitution on our items of manufacture and some of the problems encountered. It also enumerates the areas in which assistance from research organizations is considered necessary.

Introduction

The electrical industry in India has made rapid strides during the past decade and the progress has been possible in spite of the need for raw materials to stringent specifications and also of the complex nature of the processes involved. Experience so far has shown that dependence on imports continues for longer periods than originally envisaged and such dependence can be attributed to the following reasons:

1. Collaboration with manufacturers abroad whose design practices and manufacturing techniques are based on the availability of materials in their own country and who are not able to advise in respect of changes permissible for accepting materials that are locally available
2. Lack of an adequate knowledge of the availability of equivalents and the time required to establish the same for the different categories required
3. The time required to establish and then define clearly the process technology applicable in each case, once the material specifications are accepted
4. Reluctance on the part of manufacturers to develop new lines of production because of commercial considerations
5. Inadequate time that is available owing to tight delivery schedules

With so much need for self-reliance in manufacture at this critical hour, a lot of effort has already been made towards the substitution of imports for

raw materials and semi-finished items and numerous indigenous sources have been established for ensuring a steady and consistent flow of satisfactory material. Wherever such suppliers have themselves had technical assistance from a manufacturer abroad, the problem is resolved easily. In cases where there has been no such collaboration or assistance from overseas and the Indian supplier is on his own, there has to be a great deal of coordination between him and the user before the material can be certified as satisfactory for use by substitution. Depending upon the facilities available with both of them, they have to enlist such help as is necessary from research and development laboratories, who have, therefore, to be concerned not only with the individual properties of the materials but also the process technology in each case, leading to its application in the manufacture of electrical equipment.

In an effort to highlight some of these difficulties and suggest ways and means of successful collaboration between industry and research to deal with them effectively, the following topics have to be considered in detail:

(i) The substitution of imports accomplished already in the Electrical Industry

(ii) The substitution of imports for which research and development are necessary

(iii) The spheres of collaboration between Industry and Research organizations

Substitution of imports accomplished

Acquisition of know-how. Practically all items of electrical equipment are generally custom-built units, designed to suit individual site conditions and operating requirements of the systems of which they will form a part. In addition there are limitations of transport which necessitate a reduction of the weight and size of the largest package. Further the manufacturing techniques have suitably to be modified to suit the skills presently available for manufacture, using indigenous materials. The progress made so far in India and particularly at Bhopal indicates that effective and competent design teams can be built up within a short time to take care of all the problems that may arise in design, manufacture and testing and also to consider research and development for the future. This augurs well for the Electrical Industry.

Substitution of raw materials. The principal raw materials required in the Electrical Industry are:

(i)	Non-ferrous	—	Copper and copper alloys & aluminium
(ii)	Ferrous	—	Mild-steel, carbon & alloy steels, electrical sheet steel
(iii)	Insulating Materials	—	Paper, synthetic resin bonded paper, tapes (Cotton & PVC) glass-cloth, Permali, mica & micanite varnishes & paints, silicone insulating materials for class H insulation etc.

Non-ferrous metals — Paper-covered, enamelled and cotton-covered copper strips and wires have been available from indigenous sources to a limited extent out of imported copper ingots. The manufacture of glass-braided and asbestos-covered copper straps which have extensive application in the Electrical Industry has yet to be taken up locally. Electrolytic copper is still largely imported and indigenous production as contemplated now is to be expedited.

Some work has already been done in the substitution of copper with aluminium in switchgear and control boards. All the new substations are being designed to provide for the use of aluminium conductors. Development work is in progress for replacing copper busbars in 11 kV. metalclad switchgear and the conductors in 33 kV. condenser bushings. But such substitution cannot be done without extensive tests. Even for substitution in the windings of power transformers, tests are necessary to establish the soundness of processes involved, including the coating of the conductors, their jointing etc.

Ferrous metals — Mild steel plates and sections to BS 14 & 15 have already been replaced by indigenous supplies up to a thickness of 75 mm. Above this thickness, the Industry is still dependent on imports. Also the requirements of stainless steel are still imported, as this is not manufactured in the country. However, this is only a temporary phase, as plans to manufacture all these items in the country, are well underway and they should be available in the not-too-distant future.

For the cold rolled sheet steel generally used for the manufacture of control panels, control desks and capacitors, hot rolled sheet steel which is available from our Rourkela Steel Plant has been substituted.

Shortly, there would be no difficulty in obtaining our requirements of hot rolled electrical sheet steel of low loss grade suitable for the manufacture of smaller motors, from the Rourkela Plant. However, there does not seem to be any provision yet in the country for the production of cold reduced, and cold reduced grain oriented sheet steel required for the manufacture of larger electrical equipment such as generators, large motors and transformers and this is being imported. Also, the pole piece quality strip steel, which is to be manufactured by Rourkela, is not up to specification for salient pole generators and motors. However, as the cold reduced types of steel are essentially used in the larger rotating electrical equipment and transformers, efforts are being made now to ensure that it is produced by one of the steel plants to be constructed in the next plan and Government are fully aware of the urgency of this requirement.

Insulating materials — Bakelite board, grey press board (Elephantide), compressed hardwood (Permali) and other indigenously available insulating materials suitable for use on our products are being fully utilized by us. The manufacture of micanite and micanite mouldings for various applications is being established at Bhopal.

Mica bonded glass tape, bituminous compound, epoxy resins, insulating varnishes, cold setting polyesters and silicone insulating materials are still imported. These items are effectively replacing bitumen impregnated mica silk tapes heretofore used on large turbo and water wheel generators and no suitable alternatives are available at present. Thus, there is a wide field for research to find indigenous substitutes and processes. Also, indigenous manufacturers could be encouraged to manufacture these items here in collaboration with foreign concerns.

Substitution of components. The types of components generally required by the Electrical Industry are:

(i) Castings—mild steel, magnetic steel, malleable iron, aluminium alloy and brass die castings

(ii) Forgings of carbon steel

(iii) Finished components and products such as meters, instruments relays, bearings, carbon brushes, batteries, conductors, resistances,

rectifiers, pressure switches, vacuum gauges, hydrogen purity indicators, temperature detectors, thermocouples, turbine governors and controlgear etc.

Practically all types of the smaller castings have been indigenized and the initial difficulties of obtaining some of them, such as malleable iron castings and steel castings, have now been successfully solved. Wherever serious difficulties have been experienced in this regard, the designers have tried to redesign the component as a fabricated item.

The larger castings have not so far been available indigenously but with the coming up of the Foundry Forge Project of the Heavy Engineering Corporation at Ranchi, and another contemplated large foundry exclusively for the heavy electrical industry, these castings should be obtained indigenously before long.

Similarly, at present the requirements of the heavier steel forgings are not available, as required for large motors, generators and turbines as well as the special shaft forgings for traction motors. Here again, indigenous capacity is being built up and these should be available in due course.

It does seem necessary that the heavy castings and forgings required by the electrical industry are given special attention to ensure that capacity is reserved for this purpose, as these are specialized items in which producers may not be particularly interested.

It will perhaps be uneconomical for the main industry to produce the ancillary items such as meters, instruments, relays, pressure gauges, vacuum gauges etc., listed under (iii) above and hence these have to be obtained from other manufacturers. The Industry can now obtain indigenously most of the power station requirement of meters, instruments and relays.

Attempts are being made, as shown above, to get some manufacturers interested in undertaking the manufacture of the other finished components and products required by the engineering industry and which are normally obtained from ancillary industries by manufacturers of large electrical equipment.

Limitations on the reduction of imports. It is clear that the reduction of imports is a continuous process and one would be able to notice substantial progress in a period of five years. For example, on Switchgear and Water Turbines the percentage of imported materials and components to sale value can be brought down to as low as 5 or 10 per cent. On other products of the Electrical Industry such as transformers, generators and motors the import content cannot be reduced to such a low value primarily because of the extensive copper, electrical sheet steel and heavy forgings and castings which are extensively used in their manufacture and imported at present. While the electrical sheet steel of indigenous manufacture will eventually be available, the import of virgin copper will have to be continued until the Khettri Copper Mines are commissioned for helping the reduction of imports.

Apart from finalizing the specifications for materials required by the Industry, the processes have to be thoroughly investigated with reference to the materials available as many of the processes in the manufacture of electrical equipment are complex ones and have to be done under controlled conditions. This involves considerable time and effort and hence the Industry is continuously engaged in this important work.

Substitution of imports for which investigation is required

As can be expected, there are fields in which the substitution of imports is possible only after extensive and detailed investigations. No single organization, howsoever large, can undertake this stupendous task alone. Assistance in this regard from research organizations is, therefore, considered absolutely essential. We would, therefore, like to detail, as examples, a few of the numerous problems which we consider could be very usefully taken up in collaboration with research organizations.

On turbines, generators and motors, oil whirling and the effect of flexibility of the oil film in the bearings on critical speeds of shafts, is becoming a limiting factor. A suitable method of measuring the oil film flexibility, as also investigations to determine the cause of oil whirling and the preventive steps that could be taken to avoid it, could possibly be usefully dealt with in collaboration with our national physical laboratories.

Peripheral speeds in the region of 20,000 to 30,000 ft per min. are encountered in our turbines and generators. The stresses in different parts of the rotating elements and stress concentration at transions, create serious problems in design. A few examples of such severely stressed components are, steam turbine blade root assembly, turbogenerator coil binding rings and the dovetailed keying arrangement of salient poles on water wheel generators. Photoelastic measurements offer a useful method of determining these stresses and any knowledge obtained from further investigations in this field, should considerably assist our designers in choosing suitable materials and the correct proportioning of parts.

In tropical climates, the cooling water temperature for condensing the steam from the turbines in thermal power stations is high and this results in low vacuum conditions. To take avantage of the greater steam flow possible under such conditions (increasing the output thereby), the turbine blades should be made sufficiently strong to withstand the increased steam forces. Thus, the development of blade profiles to utilize steam turbines more effectively in tropical countries, is of importance and a very good sphere for collaboration with research organizations having the facility to do this. The research work involved would include the aerodynamic testing of blade profiles at subsonic, transonic and supersonic conditions. The detailed determination of flow losses and effect of blade profiles on flow separation would also need to be undertaken.

In industrially developed countries, a great deal of work is done on continuously developing better and cheaper synthetic insulating materials. In fact the development is so rapid and extensive that it could be justifiably called a 'Plastic Revolution' in this field. It, therefore, seems very necessary for us to undertake extensive research on the development and application of synthetic materials such as butyrates, polyolefins, polystyrene and various glass reinforced polyesters and ascertain their strength, mouldability, corrosion resistance and freedom from microbiological attack. The application of these synthetics for electrical insulation purposes, could be fully investigated in relation to their utility in the electrical manufacturing and supply undertakings.

The substitution of aluminium for copper has never been questioned, but matters of detail are still uncertain. At large generating stations and substations, copper is still being used for earthing. Its replacement by aluminium, though attractive from the electrical point of view, is somewhat hampered due to the lack of knowledge of its performance under soil and subsoil conditions, corrosion being the major consideration. It would

be of interest and useful to know the behaviour of earthing grids made from aluminium conductors (stranded and strip, bare or anodized) under the various types of soil and different climatic conditions.

The manufacturers should be given first hand knowledge on the production of aluminium enamelled/anodized winding wires, rounds and strips for motors and solenoid coils. The problems affecting the design and manufacture of motors and coils with these materials, should also be studied.

Fundamental research in fluid flow pertaining to hydraulic turbines and the discovery of substitute metals which have acceptable properties with regard to cavitation erosion and corrosion, will assist our water turbine engineers in developing better, more robust and economical designs for future. The cavitation laboratory being set up at the Central Water & Power Research Station, Poona would provide facilities to undertake this work in collaboration with our water turbine designers.

Research organizations for industry

Industrialization in India has not yet reached the same sophisticated stage as prevalent in the industrially advanced countries. It is evident from the few problems listed earlier, that though there are a few fundamental problems that can be tackled by our national research laboratories and organizations, by and large, operational research or development work is more essential to industry at this stage. For almost all industrial problems, there is generally a need to translate the known sound theoretical considerations into practical forms suitable for local conditions of operation and the skill of the labour available to us at present to manufacture and maintain the equipment. However, the facilities at present available in the country for this type of industrial investigation and research work, are totally inadequate. For example, a steel firm in the USA has brought out by its own research and investigation, a core-material which will not require annealing and manufacturers will be anxious to use the same, as this process can be eliminated and a saving in the cost is introduced. Though in India also, each Industry is attempting to undertake its own research it will take some more time to introduce such improvements in their supplies.

In this country we mostly have research facilities available at the universities and national research laboratories and institutes. The universities, for good reasons, generally deal with only academic problems of technology. The work being done in our national laboratories and research institutes, is generally associated with basic or fundamental research. They may not, in general, have all the facilities to deal with industrial problems and may not in all cases appreciate the urgency of the commercial aspect of such work on development, which is so essential to industry. With the resources they have, they are making a valuable contribution in their spheres of work and are playing the same role as similar organizations do in the more advanced countries.

Further, if such research is left to the manufacturer's laboratory, each manufacturer will concentrate on the research and development, which when fed into his design office, will immediately make his product more saleable than that of his competitors. There remains still the great volume of research, the results of which must be of common benefit to the industry as a whole. Once these fields are clearly understood, undesirable and often expensive duplication of effort can be avoided.

Although there is a steadily rising activity in research and development in this country, there is evidence that we need to put in still greater efforts into the discovery of new ideas, their technological application and commercial realization. For this purpose, the need of the hour is the setting up of Industrial Research Centres, associated with each major industry in the country, each of which can:

(i) Devote itself exclusively to problems relating to industry

(ii) Appreciate and accept the economic and practical considerations which will weigh with designers and manufacturers

(iii) Work on limited objectives within the time available so that sound material and process technology is established

These research centres should have sufficient facilities to make prototypes, models or pilot projects, from which design data can be gathered and the complete process of manufacture established, in collaboration with the industry they are associated with. A good example of such a research organization connected with the electrical manufacture and supply industry, is the Electrical Research Association in Great Britain.

These research centres for each major industry, could possibly be set up by Government in keeping with the present trend in the country, but in our view, it may be better if they are raised by the members of the concerned industry themselves (public and private undertakings). The membership of these units should not be restricted to the manufacturers only, but open to the users of the equipment also, e.g. State Electricity Boards, Steel Mills, Railways etc. who should contribute their share to the centre in the form of knowledge as well as funds. Of course, financial assistance from Government for providing certain expensive facilities like computers, analysers, etc. would definitely be required.

Until such research centres are fully in operation, it is necessary that the facilities already available with the Electrical Industry have to be utilized to the extent possible. At Bhopal, there is a well-equipped Testing Laboratory as part of the Research & Development Unit which will be prepared to give any assistance to the Industry as required.

The possibility of initially establishing a Research Information Centre for each industry can also be considered as this could ultimately be amalgamated with the proposed Research Centre. Such centres could be created almost immediately with a reasonable investment. The centre associated with the electrical industry, would generally have the following aims and objectives:

(i) To find out the existing position on raw materials, components and the processes used for each type of equipment and their costs

(ii) Segregate the imported items from the indigenous items for each product

(iii) Catalogue the technical and physical properties of all imported components and raw materials and list the processes and their use by different manufacturers

(iv) Collect data on the indigenous capacity available in ancillary and other industries for supplying the requirements of the electrical industry, and also data on the performance and particulars of such components and assess the demand for these from time to time

(v) After coordinating the data obtained under (i), (ii), (iii) and (iv), provide a technical information service to its members which would enable them to benefit from each other's experiences in the substitution of imported items by indigenous ones

This service should definitely cut down the wasteful expenditure at present being incurred by each new plant in trying to locate suitable indigenous equivalents of components and ancillary products used by them.

Conclusion

This country is faced with the twin problem of shortage of foreign exchange and the limitation on time to become self-reliant, as far as the Electrical Industry is concerned. The need to maximize independence from imports cannot be underestimated. With this in view, it is necessary to define the fields in which investigation is required and others in which research is considered necessary, so that all available facilities and technical know-how are pooled together for coordinated effort, which will avoid duplication. Such a coordinated approach between the Electrical Industry and research organizations will definitely help to resolve many of the difficulties and problems being encountered from time to time in the common endeavour.

Glass-lining of Chemical Equipment

Regional Research Laboratory
Hyderabad

The chemical, pharmaceutical, foodstuff and dyestuff industries require reaction vessels which should have sufficient resistance to acids and alkalies at elevated temperatures and pressures. Ferrous and non-ferrous metals and their alloys are badly corroded when used as reaction vessels by the above-mentioned industries. In order to meet this challenge the glass-lined equipment was developed. The glass-lining is an enamel coating on the surface of steel and is much superior in its inertness towards the reaction of corrosive materials as compared to the vitreous enamels. In this manner, the nonreactivity of glass is combined with the structural strength of steel to result in an ideal vessel for carrying out different reactions. In addition to this, the glass-lined equipment has the following advantages:

(a) It has a smoother surface than most finely polished metals and other surface coatings and therefore the cleaning and sterilization which is of great importance in the pharmaceutical and foodstuff industries is much easier.

(b) The glass-lining has no catalytic effect of its own on the reactants.

(c) Its abrasion resistance is also good.

The work on glass-lining can be divided into two aspects, one being the desirable composition of steel and its fabrication into vessels and the other, the development of suitable chemical resistant glasses to be fused on the surface of the metal. The steel required for glass-lining should have not more than 0.03 per cent carbon. Unfortunately this grade of steel is not being manufactured in the country. Work on the development of enamels for glass-lining of equipment was started in the Regional Research Laboratory, Hyderabad, about three years back. The indigenously available 0.2 per cent carbon-bearing steel was used for this purpose. About 100 different types of frits were prepared and tested by the powder method for their chemical resistance at elevated temperatures. A process was developed to successfully glass-line steel of such high carbon content by employing an intermediate coating of different transition group elements. Flat test pieces about 3 in. × 3 in. and thimbles 1 in. diam. × 5 in. ht were enamelled at 900°C. and test for their chemical resistance towards boiling hydrochloric acid was carried out as per the standard procedure. Those compositions whose acid solubility was less than 0.08 g./sq.m. per hour were applied on open vessels of 8 and 22 litres capacity. These were then tested for continuity of glass coating by the electrical resistance test. Those which were found to be free of imperfections were then subjected to 20 per cent boiling hydrochloric acid for 100 hr and were once again tested by the electrical resistance method. Only those compositions were considered promising which stood the acid boiling test satisfactorily. A total of eight, 8 litre

capacity and four, 22 litre capacity vessels were thus glass-lined. Thermometer pockets and anchor type stirrers were also successfully glass-lined in this manner. Experiments were then conducted to glass-line straight and curved pieces with and without joints. Ten out of the above-mentioned 100 compositions were found to give satisfactory results. Further experiments are in progress for glass-lining still larger vessels. Action is being taken for the establishment of a pilot plant for fabricating 100 litre capacity vessels by utilizing the technical know-how developed at the laboratory. While glasses as a family are inert to chemical action, none is universal to all reagents and hence more than one composition is necessary for glass-lining in order to meet the varying needs of the industry.

As mentioned earlier, many industries of both civil and defence importance depend on the glass-lined equipment for performing different processes. Since there is no established firm engaged in the manufacture of standard glass-lined equipment, a venture in this direction is highly desirable. Two or three firms are attempting to make this item in the country, out of which one firm is planning to do so by foreign collaboration. The import data for this item are not available but all the requirements of the country are met by imports only. It may be estimated to be of the order of a few crore rupees per year. If produced indigenously, imports may be reduced or eliminated altogether. Further improvements in the quality of the product can be achieved if mild steel of low carbon with a consistent quality is available in the country.

In view of the above, it may be seen that the laboratory has made a considerable progress in this direction and is in a position to successfully fabricate the glass-lined equipment in the near future.

Import Substitution of Spares in Organic Chemical Industry

R. M. KHANDWALA
Union Carbide India Ltd
Calcutta

The major organic chemical industries in India have been established with the foreign know-how, foreign proven equipment to suit the stringent process conditions like corrosive chemicals at extreme pressures and temperatures. These equipments require special non-corrosive materials, special fabricating technology and testing facilities to conform to various manufacturing standards which are now gradually developing in the country.

The major imported equipments have been high pressure, high capacity pumps and compressors, convertors and heat exchangers made of special material such as stainless steel, copper etc., explosion proof electrical equipment in view of the explosive nature of the industry, process control precision instruments and recorders, process inter-locking system to safeguard plant and personnel.

As a result of the above special imported equipment it has been necessary for the industry to look to the foreign suppliers of the equipments for the necessary spares for maintenance. These spares were readily imported in the past but with the present foreign exchange shortage the industry has to find ways and means of procuring the spares locally. In order to conserve the foreign exchange in the foreseeable future it is advisable to develop permanent local sources for the supply of imported spares.

Methods of reducing imported spares

The following methods are by no means new, however, they have an added significance in the light of present foreign exchange shortage in the country.

Minimizing usage of spares by effective preventive maintenance. By periodical planned inspection of the plant equipment, it is possible to uncover conditions leading to production break-down and to repair such conditions while they are still in am inor stage. This prevents total breakdown of machinery and makes it possible to recover machinery parts while still in a repairable stage.

Salvaging of spare parts. In many industries, when a machinery part is replaced with a spare, it is standard practice to junk the recovered part. No effort is made to salvage the part. By proper salvaging programmes utilizing such modern techniques as metallizing, metal-locking etc. industries can save substantial amounts in foreign exchange.

Standardization. Standardization of equipment and spares is a powerful tool in the battle to save foreign exchange. It also helps to keep

stores inventory down. Considerable savings can be made in the foreign exchange component of plant investment by applying standardization at the design stage.

Fabrication. Wherever possible spares should be fabricated locally. Raw material could be imported or local. In the case of imported raw material, the only exchange saving is in the fabrication cost. In many cases less durable local material can be substituted for imported material. In this instance total foreign exchange can be saved but this fact will have to be balanced against high costs resulting from frequent replacement of the spare.

Replacement of imported equipment with indigenous equipment. In a developing country like India, it is quite possible that equipment which was not available at the time of plant erection, is now locally manufactured. As an extreme measure the imported equipment may be replaced with indigenous equipment. This can turn out to be very costly and can only be justified by the necessity of keeping the wheels of industry going in a national emergency.

All future expansions should be planned with indigenous equipment as far as possible.

Can imports be ruled out completely ?

While we are considering methods for reducing or eliminating imported spares, it will not be out of place to point out that a policy of complete self-sufficiency in the matter of spares is impossible. A policy of manufacturing each and every item required by industry will involve us in difficulties impossible of solution.

If indigenous items are used without regard to costs it is bound to lead to higher prices of the final product. The high cost of our products will automatically deny the country the opportunity of penetrating foreign markets. Exports can be maintained on a long term basis only on the solid foundation of lower costs. Indiscriminate use of local material without due regard to costs can lead to a vicious circle of high costs at home and a dwindling foreign market.

If circumstances force the industries to utilize locally available material in spite of heavy costs, exports will have to be heavily subsidized till such day when the economical local manufacture becomes a fact.

Recommendations

It is suggested that a committee of the representatives of the chemical industries and the Central Government be formed to:

(i) ascertain the heavily imported spares commonly used by the industry and to develop local sources for their economical manufacture.

(ii) assist local manufacturers in obtaining necessary imported raw materials for the manufacture of spares.

(iii) obtain information from the constituent industries about the excess spares that they might have and also about the discontinued equipment with a view to distribute them to others who are interested in its utilization.

(vi) Develop sources in rupee-payment countries. At the same time the Central Government especially the Development Wing can help this process of self-help by doing the following:

(a) Encourage local fabricators to comply with internationally approved standards such as ASME Code.

(b) Develop local sources for special alloy steels. Whenever such projects are in hand they should be completed expeditiously.

(c) Encourage research for substituting imported materials with local materials.

(d) Assemble all available information about fabricators all over India and disseminate this information for use by industries. This information should include their names, addresses, specialities and other capabilities. This should be a continuing process for years to come.

Titanium for Construction for Chemical Plant

S. L. CHAWLA
Indian Institute of Technology
New Delhi

Titanium is superior to copper and stainless steel particularly in corrosion resistance and high-temperature strength. Therefore, in spite of its high cost, it can replace both in some of their applications with overall economic advantage. Our resources of copper and stainless steel are inadequate. Besides chemical industry, defence needs of the metal are extensive and probably more pressing. Hence it should get priority for production. The economic aspects, fabrication techniques and production from indigenous sources are discussed briefly.

Introduction

Titanium has been developed as a military metal of importance during the previous decade. The advances in its technology leading to increased production, notably in USA have been due to the impact of Korean War. It did not find much use in chemical industry during previous decade on account of its high cost and to some extent due to lack of knowledge about its properties and adaptability. But during the last ten years the prices have fallen to 1/3rd of previous value and extensive studies have been made on its corrosion resistance and fabrication techniques. This has led to its increased production and far greater application in chemical industry[1] as is evident from the data presented in Table 1.

Apart from chemical industry, which consumed a fraction of a per cent of its production before 1956 and 7 per cent in 1965, the major portion of

Table 1 — Annual production of titanium in USA and its consumption in chemical industry

(in tons)

	Total production	Consumption for chemical plants	Percentage of total consumed for chemical plants
1955	1900	5	0.27
1956	5100	5	0.1
1960	5000	100	2.0
1961	5000	150	3.0
1963	6750	375	5.5
1964 (est.)	7500	500	6.6
1965 (est.)	9000	625	7.0

NOTE—The present cost of titanium per kg. in USA is \$6.60 for plate and bar \$10.00 for sheet and \$18 to 24 for tubing

Table 2 — Comparative properties of titanium, copper, stainless steel, mild steel and aluminium

	Titanium (commercial)	Titanium (alloy)	Copper (annealed)	Stainless steels	Mild steel	Aluminium (commer.)
Tensile strength (kg./sq. mm.)	40-70	70-83	22-25	47-63	18-25	15-25
0.1% proof stress (kg./mm.^{2})	23-38	47-75	6-8	—	—	6-12
Elongation (% on 2 in.)	20-30	12-20	50-60	—	20-60	5-20
Density (g./cc.)	4.51	4.51-4.56	8.94	7.74-7.8	7.86	2.7
Specific heat (cal./g./ °C. at 50 °C.)	0.126	0.126	0.093	0.12	0.11	0.22
Coefficient of thermal expansion (10^{-6}/°C.: 0-100 °C.)	8.9	8.9	14.4	16.0	11.9	24
Melting point (C.)	1660±10	—	1084	1450-1500	1535	660
Maximum operating temp. (°C.) Intemittent service	580	600	300 (arsenical)	525	400	230
Continuous service	430	450	150-200	400	275	170

the rest has gone for defence requirements in aircraft industry and ordnance factories. The above ratio should be higher towards chemical industry in a developing country.

Importance

Factors which determine the selection of a material for chemical plant are well known. The over-riding factors that determine the selection of this material are its superlative corrosion resistance, high creep strength and high strength-to-weight ratio generally in the order mentioned. The deterrent factor is its cost. The present cost of titanium equipment is 2 to 3 times that of stainless steel, but its life expectancy and maintenance saving justify its use. Another factor of prime importance for us in this country is that we have to adopt ourselves to the use of those metals for which raw materials are available in this country. Copper and its alloys find extensive application in marine conditions. But our resources for production of copper are negligible. As compared to copper the corrosion resistance of titanium is far greater and its strength-to-weight ratio is four times that of copper. Further, we do not have any source of nickel for the production of stainless steel. Titanium can replace stainless steel in a number of its applications. If titanium can lend itself to uses in countries where copper and nickel are available, there is every reason to believe that large tonnage of it will find use in chemical industry when it becomes available in this country. Its engineering properties (Table 2) also compare favourably with those of copper and stainless steel.

Corrosion resistance

As a material of construction for chemical plant, titanium has no equal in its chemical resistance to seawater, wet chlorine, chlorides, hypochlorides, chlorates, perchloric acid, acetic acid, urea, nitric acid and chromic acid. It is resistant to oxidizing media in the presence of chloride ion, where stainless steel is subject to pitting. Its resistance to reducing media can be

enhanced by alloying with 0.15 to 0.2 per cent palladium. With the increase of pressure and temperature in modern technology, the high creep resistance and high strength-to-weight ratio are the properties to be reckoned with. Detailed list of its applications, properties and composition is given else where[2–4]. Here two or three instances are cited to compare its corrosion resistance with the conventional materials in specific cases. Titanium alloy valve plates[2] have completed over 20,000 hr service in an ammonia synthesis compressor handling nitrogen and hydrogen up to 55 atm. which is more than 3 times of the average life obtained with steel valve plates, and titanium alloy springs have given lives in excess of 22,000 hr in the same condition compared with about 300 hr for stainless steel. The life of stainless steel nitric acid still[1] is 18 to 20 months while the life expectancy of similar titanium still is 8 to 10 years. Stainless steel coils were used to heat 70 per cent nitric acid at 77°C. in a reaction vessel. By using titanium 'coils' reaction was carried out at 149°C. This resulted in a substantial increase in output. The cost of titanium coil is a little over twice of stainless steel. These are not isolated instances, such examples can be multiplied.

Titanium has excellent resistance to stress corrosion cracking, corrosion fatigue, pitting corrosion and is non-catalytic in nature. However, it is prone to crevice corrosion. This can be remedied if crevices are large enough to permit free flow of solutions so that concentration changes do not take place. In fact, skilful design and employment of novel fabrication techniques are necessary to take advantage of the properties of a new metal. For example the method of sandwich construction, using an intermediate layer of high tensile steel wire wound continuously under tension, can considerably reduce the plate thickness in a pressure vessel.

Economics of equipment

Ultimately it is rupees and paise that rule the selection of an equipment. Therefore, the basic factors that matter in the selection of a material of construction for a chemical plant are: the cost of the equipment, its life expectancy, influence on the process, maintenance saving and continuity of production. Although the basic cost of titanium equipment is nearly three times of stainless steel, yet it is obvious, from the examples cited in previous section, that in ultimate analysis in terms of cost per unit product it is considerably cheaper. From economic standpoint this consideration is most important. A measure of the increase in demand or popularity is the availability of standard equipment on 'off the shelf' basis. In fact, pipes, pipe fittings, valves etc. can be obtained on this basis in titanium producing countries. It is expected that cost will be further reduced in a couple of years.

Military applications

In the present context it may not be out of place to mention briefly direct defence applications. Mainly on account of its high strength-to-weight ratio it finds application in aircraft industry, naval ships and other equipment as it reduces dead weight thereby improving manoeuvrability. Satisfactory performance at high temperature is required in the jet-age. In this it beats both aluminium and stainless steel, the former on account of its high-temperature strength and the latter on account of its low density. In jet engines, it is used mostly for compressor blades, turbines discs, compressors and turbine lines, replacing stainless steel and alloy steel. The low weight of the metal, in conjunction with resistance to marine environments, offers in naval vessels improved manoeuvrability, increased

range, less preventive maintenance and reduced power costs. In the case of air borne equipment and man-carried equipment its low density is a decided advantage. It is for these reasons that over 80 per cent of its production is used for military purposes, where cost is not always a primary consideration.

Fabrication

Fabrication cost of titanium is nearly the same as that of Hastelloy, stainless steel, and other high alloy steels. Welding is the major technique employed. On account of its high reactivity the molten metal has to be enveloped in an inert gas like argon or helium. Therefore, inert gas-shielded-arc welding process is employed for fusion welding. It is also amenable to hot and cold forming operations like forging, rolling, extrusion and drawing. Its machining is similar to stainless steel, i.e. the same cutting tools, tool angles and tool speeds are used.

Casting in titanium equipment is costly as the operation is complicated on account of high reactivity of molten titanium towards oxygen, nitrogen and silica. Therefore, melting and casting have to be done in an inert atmosphere. Otherwise, by virtue of its low thermal expansion and low susceptibility to gas porosity it should give good castings. However, it has been reported[5] recently that prices of castings have dropped down considerably by use of consumable electrode skul-type furnace to produce molten titanium for casting. It is claimed that the prices compare well with that of high alloy steel castings.

Lining with an expensive corrosion resistance material and backing with conventional material is an age-old technique. The coefficient of thermal expansion of steel and titanium is sufficiently close to permit the use of this technique up to a moderately high temperature. The lining is generally loose and mechanically fastened at flanging areas.

Production

Extraction of titanium is beset with difficulties on account of its high reactivity. Rutile and ilmenite are two important ores used for its extraction. Rutile is almost pure TiO_2 and ilmenite contains 30 to 50 per cent of iron oxides. Therefore extraction from the former is comparatively simpler and is practised as far as possible. Our resources of rutile are scanty. We are one of the large producers of ilmenite and our resources of the titania rich ore are plentiful. Indian ore contains over 60 per cent TiO_2 and 32–34 per cent iron oxides.

Manufacture of the metal from ilmenite requires the separation of iron as first step, which is not easy. There are three methods for the beneficiation of ilmenite to TiO_2. In one method sulphuric acid is used to convert iron oxides to ferrous sulphate, which can be removed as a by-product. In the second method — called thermal method — the oxides of iron are reduced at high temperature producing pig iron, which is a useful by-product. The third method consists of preferential chlorination of iron in the first stage followed by distillation and condensation of the chloride. Sulphur, which is required for the manufacture of sulphuric acid in the first method, is in short supply and the by-product is not easily saleable. Therefore we shall have to weigh carefully between the economics of chlorination and thermal methods for the adoption of either of the two.

The beneficiated ore is chlorinated at high temperature in the presence of carbon to produce titanium tetrachloride, which is distilled off and

condensed. The pure titanium tetrachloride is reduced under very closely controlled conditions with magnesium to give sponge titanium or with sodium to give titanium granules. It may be mentioned in passing that the surplus chlorine available in the country shall find a fruitful outlet in this process.

In conclusion, it is suggested that a plant for the production of 5 tons per day of titanium ingot should be located near Alwaye where raw material, i.e. ilmenite, cheap power and excess chlorine, are readily available.

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Research and Development : Dry Battery Industry

N. C. MEHTA
Union Carbide India Ltd
Calcutta

Introduction

Manufacture of dry batteries in India started in 1930. Up to 1948, raw materials and processed parts were imported and assembled into products. Thus production was completely import based. Product volume was small, import restrictions were unheard of and local industries which could supply raw materials and equipment just did not exist. The climate for local industrial growth in respect of new areas was not favourable.

Even in 1948, India's foreign exchange resources were considered to be substantial and there was no incentive for development of either local industrial know-how or manufacture of equipment and raw materials as these would have been considerably more expensive than their imported counterparts. It was in this climate that as far back as in 1948, the major dry battery producers in the country decided that a Development Group be organized to investigate sources of local raw materials and equipment and to develop suitable manufacturing techniques.

Development group — organization

In the industrial economy then existing, this was considered a luxury few could afford because of the resources required. It was not easy to get personnel with adequate training and experience for such work in India. For this reason, services of competent development engineers from USA and Europe were requisitioned and a group was organized under their guidance for actual development work. This Group was provided with adequate laboratory facilities for testing of raw materials and processed parts, equipment for manufacture of development samples and product testing facilities. This called for an additional outlay of capital which in those days was generally considered non-productive. From such a modest beginning, this Group has now tripled in size and necessary facilities have been expanded to meet its growing requirements. Significant work is being accomplished today by this All-Indian Group.

Development functions

In the initial phase, the Group was assigned the task of making recommendations for development of:

(a) Local sources of raw materials

(b) Indigenous manufacture of component parts and equipment

(c) Improved manufacturing techniques and new processes

(d) Inspection methods and procedures

The second phase of their responsibility was to indicate:

(a) Design changes in existing products to improve quality, reduce foreign exchange content and reduce manufacturing cost

(b) New product lines to meet changing needs

(c) Equipment design and fabrication in India

It was considered that skills developed in these areas would establish a firm base for future healthy growth of this industry.

Development group — recommendations

A critical study of the industry indicated four major areas under which work was to be organized:

(a) To set up additional manufacturing facilities for critical raw materials and processed parts

(b) Develop small-scale ancillary industries for component parts and suitable packing materials required by the industry

(c) Work in close association with existing local industries to develop sources of raw materials, equipment and spare parts

(d) Indicate minimum import of raw materials, equipment and spares necessary for the industry to maintain anticipated growth rate in light of local industries' inability to supply the same over a ten-year period

New manufacturing facilities

As a result of extensive development work, the industry has:

(a) Ore Milling Plant for the supply of milled materials to desired specifications

(b) Metal Rolling Plants for zinc strip and circles for dry battery containers

(c) Carbon Products Plants for battery electrodes

(d) Facilities for manufacture of flat cell 'Duplex' electrodes.

Acetylene black required in dry battery manufacture is also expected to be indigenously available in a year or two. Thus the industry has made considerable progress in attaining sufficiency for critical raw materials.

Preparation of technical specifications

The industry had to prepare technical specifications for raw materials, equipment and spare parts before starting investigations for their local procurement. Use of import specifications for local procurement was not considered desirable as it was felt that then existing local industries will not be able to manufacture raw materials, equipment and spare parts to rigid import specifications. Each specification, therefore, had to be thoroughly studied to decide the 'functional minimum' necessary to maintain product quality. This work was indeed most demanding.

Techniques of evaluation of local substitutes

Simultaneously, programmes and techniques for evaluation of local substitutes were developed to meet the specific needs of the dry battery industry. This was necessary in view of the fact that complex electro-chemical reactions involved in the conversion of chemical into electrical

energy are not well defined and hence not fully understood. In addition to this, effect of each substitute on mass scale manufacturing processes, human skills, process scrap and product quality had to be studied both on laboratory scale and through extensive production trial runs.

In any well planned scientific and technical evaluation programme, it is customary to study effect of one variable at a time. Because of this approach, in the initial phase of development work, the physical volume of work was considerable. Since then, well-known statistical techniques of design of experiments have been advantageously used in the development work.

Keeping a complete record of all work done is a normal practice in any research and development laboratory. However, it is often noticed this is not rigidly followed and desired information is not available because of incomplete records. This leads to duplication of work. Procedures, therefore, had to be developed to preclude such an occurrence. In addition to this, periodically, need for complete records was impressed on all personnel connected with research and development work.

Vendor development

Standard procedures given below were followed for developing local vendors:

1. Preparation of vendor list for each item or groups of related items
2. Sending specifications for vendor study and requesting samples for test
3. Frequent mutual discussions with vendors to iron out problems involved
4. Procurement of bulk supplies for evaluation
5. Vendor approval

The vital step in the Vendor Development Programme was the technical guidance given to the vendor through frequent mutual discussions with their technical personnel, followed by visits to their works for on-the-spot study of the problems involved, and develop a possible solution. This created mutual confidence and respect which have yielded spectacular results.

Consistency of supplies is very important in any manufacturing operation as this affects product quality and manufacturing cost. In some cases, this fact was not appreciated by the local manufacturers. Vendor History Cards had to be prepared showing the effects of inconsistent supplies on manufacturing operations and product quality etc., to develop this outlook. Since then, this has been introduced as a standard inspection procedure which is very helpful in vendor evaluation.

Second essential industrial requirement is continuity of supplies of approved quality at the appropriate time. In order to ensure this, alternate sources of raw material and spare parts must be developed as soon as possible. If this could not be immediately done for various reasons then it should be kept under constant review. Necessary steps should be taken to develop the same at the earliest opportunity.

In the developing industrial economy, it is possible that newly established industries can supply raw materials, component parts, equipment and spares, which were previously imported. The Dry Battery Industry has, therefore

been constantly studying progress of new industries with a view to procure their needs from the newly developed industries.

Because of the concerted efforts, the industry has been successful in developing local sources of manganese dioxide, non-ferrous metals, chemicals, paper boards, plastics, metal parts, equipment and spares which has substantially reduced foreign exchange needs of the industry.

The Indian Standards Institution have been very active in formulating raw material and product performance standards in close cooperation with the industry. These standards have been very helpful in developing local substitutes. The Dry Battery Industry is very grateful to the Indian Standards Institution for their keen and continued interest.

Export for minimum import needs

It was mentioned earlier that in spite of all possible efforts, there may be areas where local substitution is not possible and, therefore, there will be a certain minimum import necessary for the industry. The only way to bridge this gap is through exports. The industry realized as far back as 1960, that it must export its products to earn at least a part of its foreign exchange requirement. Considering the fact that export markets require highly sophisticated products with excellent appearance to meet the severe competition from highly developed countries, it must be recognized that export effort of India's Dry Battery Industry has been very bold and its performance recommendable.

New and improved products

The industry has been able to introduce new and improved products to meet consumer needs because of experience gained in the field of research and development. However, it must be mentioned that for accelerated development it has been necessary to buy know-how from developed countries in order to bridge the gap in a short period.

Introduction of new battery systems in India has been periodically explored by the industry. If new battery systems are required to be manufactured in a short time, then it will be very necessary to buy technical information relating to their manufacture. Of course, this can be developed in our institutions through extensive research. However, this procedure will considerably delay the introduction of new battery systems in India. It is, therefore, prudent to buy the existing know-how and develop it further in place of developing what is already known.

Defence requirements

Dry Battery Industry is justly proud of its accomplishment in meeting exacting defence requirements. New products have been developed and mass produced for defence in a very short period of time. Here again, know-how had to be obtained from developed countries to cut short the development time. The industry is constantly striving hard to meet our defence requirement.

Achievements

By carefully following techniques outlined above, the Dry Battery Industry has been able to significantly reduce foreign exchange content of their products in a relatively short period. This has enabled them to increase product volume several fold, thereby satisfying growing domestic

demand for their products and at the same time provide for export. This pragmatic and realistic approach has helped the industry in developing considerable confidence in their ability to meet unforeseen demands.

Recommendations

Following recommendations are based on significant achievements in the Dry Battery Industry :

(a) Each production unit develop its short and long term development programmes for local substitution. This study should also indicate the minimum import requirements which could not be met from local sources.

(b) Such information on related industries be compiled. This will indicate research and development effort required and the minimum foreign exchange needs of each group.

(c) An All-India study of this nature will indicate total minimum annual foreign exchange requirement for maintenance and growth. This will also show total research and development effort required on a national basis.

This study will also help establish priorities :

(i) For new industries to be developed to support and maintain existing industries. It may so happen that a low priority industry has to be developed for better utilization of existing industries.

(ii) For technology to be developed for industrial growth and development. This can be used as a starting point for research and development programmes to be initiated at national research laboratories and private research institutions. Such a directed effort to research and development will avoid duplication of efforts and lead to better utilization of available resources.

(iii) The minimum export effort required on a national scale to maintain industrial growth. The export performance can be studied in relation to the minimum requirement which will indicate well ahead of time the steps to be taken to maintain or improve export performance, e.g. a new approach to import licensing policy for raw materials and equipment and changes in the incentive schemes which will assist industry in meeting export targets.

The above analysis, therefore, shows that for a well planned industrial growth with maximum self-reliance, a properly coordinated and directed programme of industrial research and development is absolutely necessary. This is our key to progress.

Semi-mechanized Machine for Preparing Self-set 85 % Magnesia Insulation

R. N. VOHRA & B. G. THAKER
Central Salt & Marine Chemicals Research Institute
Bhavnagar

Magnesia (85%) is universally used for thermal insulation. A machine is described which will produce pipe sections from 85% magnesia obtained from seawater bittern. Feed for the machine is calculated quantity of magnesium carbonate and asbestos. The machine is simple in design and is primarily meant for small scale manufacture.

Magnesia 85% insulation is a product of not less than 85 per cent light basic magnesium carbonate and 10 to 15 per cent asbestos fibres. Its thermal insulation properties up to a temperature of 300°C. are well known. The process for production of self-set 85% magnesia was first described by Abraham in which dolomite was used as a starting material for magnesium carbonate.

In the semi-mechanized moulding machine which will be described in detail later, is the one where the main operation of the process takes place, i.e. setting of magnesium-carbonate mixture. It is necessary to sketch quickly through the process before this machine is described.

The CSMCRI starting material for this process is seawater bitterns or seawater. 29°Bè bittern contains approximately 52 g. magnesium/litre. This is treated with the calculated quantity of soda ash to produce magnesium carbonate trihydrate. Alternatively seawater, which contains 1.27 g. magnesium/litre can be treated with lime to produce precipitate of magnesium hydroxide. The slurry of magnesium hydroxide is thickened and washed to remove soluble salts. This slurry is carbonated with clean carbon dioxide from stack gases to form normal carbonate.

Magnesium carbonate formed by either process is vacuum filtered. It is mixed with long fibre asbestos in proper proportion and repulped with cool water. The quantity of water added at this stage controls the density of final product. The slurry is then preheated to 55 to 60°C. with live steam in preheater and then fed into the mould. After about 11 to 13 min., conversion to basic carbonate is complete and the charge is set in the moulds. The final product is removed from mould and machined to clean the outer surface. It is cut into two halves longitudinally and is ready for use.

Moulding machine

It consists of two moulds, each nearly three feet long on a vibrating table, vibrations being given by cam arrangement. The mould in proper consists of an outer jacket and an inner core in which hot water is passed in series. The mould is designed so as to obtain lagging which will fit 1 in. pipe.

Dimension and design of mould can be varied to obtain laggings which will fit any required size of pipe; or blocks can also be prepared to lag vessels containing hot process liquids. At the top of cavity of mould, there is a ram which fits exactly on the cavity. The ram is attached to a rod, where lower portion is hollow for hot water circulation through mould. At top, the ram is attached to a lever arrangement for lifting the ram through a short distance. Outer periphery of the mould is attached through a sleeve and arm arrangement to lifting screws. A ring is rigidly attached to the mould slightly above the sleeve, which will help arm and sleeve to lift the mould.

The mould is placed on a grooved disc, which is fixed rigidly on the vibrating table. Clamps are attached to the mould, so as to keep it in position at the time of vibrations, set up by vibrator. These clamps can be turned by handle at the time of lifting the mould. Magnesium carbonate, asbestos and water slurry from preheater are poured into the cavity of mould through a funnel, the ram being lifted up, and clamp being rigidly fixed with the mould. The vibration is started immediately, so as to remove air bubbles from the charge. As soon as the cavity is full, the vibrator is stopped and hot water is started through a flexible tube to the jacket, which after passing through the core, goes out from the bottom of core. After 13 min. heating material is set. At this point, hot water circuit is stopped and clamps are removed by turning the handle.

When the main drive is started, the mould is lifted up, through the required distance, by the lifting screws. The ram keeps the set material in its place on the platform. The inner core is moved down by lever and pedal arrangement and is taken out completely by removing an eye bolt from jaw of lever. The casting (magnesia insulation) is removed manually from the platform, after lifting the ram up.

After removing the product, mould is brought down to its previous position and cycle is repeated.

Time for one cycle:

Feeding of material and vibration time	...	5 min.
Setting time	...	13 min.
Lifting of mould and removing the product	...	5 min.
Total	...	23 min.

The machine is being fabricated in this institute. It is simple in construction and is being made of indigenous materials. It is primarily meant for small scale manufacture.

Desalting Saline Waters with Ion Exchange Materials

N. KRISHNASWAMY
Central Salt & Marine Chemicals Research Institute
Bhavnagar

The application of ion exchange resins and membranes for reducing the salt content in natural waters is indicated. The electrodialysis technique using indigenously prepared ion exchange membranes is proposed to be investigated for desalting saline waters from Rajasthan area.

Rapid industrialization of any country puts a heavy demand on water requirement of proper quality to meet the needs of industry as also the agricultural and domestic needs. Our country is just now at this stage of development where tapping of all available water resources to meet all the above demands will be very useful indeed.

While seawater has the highest dissolved salt contents, other water sources which are known as brackish contain a varying degree of salt content. Perusal of scientific and technical journals will refer to some one process or the other being investigated to convert saline/brackish water to water for industry, agriculture or domestic use.

At the outset it must be pointed out that it may be easier to obtain water for agricultural and drinking purposes from brackish water than to obtain pure water for use in industrial boilers etc. For agricultural purposes it will not be necessary to remove all the dissolved salts but suitably treat the water to make it fit for agriculture and similarly for domestic use reduction in hardness and removal of harmful pathogenic constituents will help. But for water to be used in high pressure boilers or for refrigeration coolant water it will be necessary to provide water with little or no salt content and for this purpose proper treatments will have to be carried out based on the raw water composition.

From time immemorial, various methods have been adopted to treat brackish waters. Among the well-known methods may be mentioned the Zeolite or Permutit process using natural green sands/alumino silicates. A phenomenal advance in the field was made in 1934 when synthetic organic ion exchangers were announced. These resins, which can be synthesized in the laboratory to specific needs, have been very widely used and as a result of their application in water treatment, demineralization etc. the technique of ion exchange has come to be recognized as an important unit operation in chemical engineering technology. Today a variety of synthetic ion exchangers are available for different applications among which water treatment stands out foremost.

Realizing the importance of the application of these resins for conditions existing in our country investigations were started in NCL, Poona to prepare

these exchangers from indigenous sources. Prior to this at the Indian Institute of Science, Bangalore the synthesis of these exchangers and other contact materials for fluoride removal from water had been investigated. As a result of the investigations carried out at NCL two ion exchangers, viz. a cation exchanger from cashewnut shell liquid and an anion exchanger from melamine are both being commercially produced in the country. Licences for the production of styrene based cation exchangers have been granted to three firms and are awaiting production.

The CNSL cation exchangers from NCL has been widely used by industry in water treatment plants and in the laboratory it has been used along with the melamine anion exchanger for treatment of different types of waters.

The economics of treatment is governed by the initial salt content in the water. If the raw water contains more than 5000 p.p.m. than the frequency of regenerating the resin for reuse will become greater and more chemicals will be needed. Another technique employing ion exchange materials but in the form of their membranes does not need chemicals for regeneration. A source of d.c. power helps to transport the ions in opposite direction through these membranes because they have peculiar properties unlike ordinary membranes. These membranes are used in stacks in cells called electrodialysis cell, and highly saline water are treated by this technique to waters with a certain amount of salt. It is not possible or economical to desalt the solution completely as the electrical resistance will be high if all the salt is removed and power consumption will be high as also the efficiency will be lowered. Hence, by this technique the salt content is brought to a certain optimum level which could be now treated by the conventional ion exchange resins.

In the treatment with ion exchange resin different techniques are possible. These are (1) simple column treatment, (2) multiple column treatment, (3) reverse deionization, and (4) monobed deionization. In the first two methods one or more of cation and anion exchange resin columns are used and the water to be desalted passes through the cation exchanger first and then through the anion exchanger. In the third method the water first passes through the anion exchanger before passing through the cation exchanger. In the monobed technique the cation and anion resins are mixed in equivalent quantities and there is saving in floor space due to simplification of equipment.

According to the Hoon report covering investigations of waters from various areas in the Rajasthan canal many of the waters found are highly brackish and need treatment before use.

Results obtained with some Rajasthan water sample both by the use of resins and the electrodialysis technique have already been published[1].

Recently, the electrodialysis studies are being scaled up and it is intended to study use of these samples of water in the bench scale unit proposed to be set up in this institute shortly. The necessary ion exchange membranes will be fabricated from indigenous sources and the equipment assembled with local resources.

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Chemical Plant Designing in India — Its Role in Import Substitution

RAJESHWAR KUMAR GUPTA
D. C. M. Chemical Works
New Delhi

Introduction

In view of the country's defence requirements and the consequent foreign exchange stringency, it is imperative to make systematic studies in import substitution. Chemical Industry which requires vast expenditures of foreign exchange for know-how, engineering, machinery in the first instance, and on spares, and in some instances, raw materials on a recurring basis, offers a great scope for import substitution.

The estimated requirements of some important heavy chemical plants during the Fourth Five-Year Plan period is as follows[1]:

Plants for	Additional annual capacity (tons)	Estimated fixed investment (Rs crores)
1. Fertilizers—N_2	1.36 million	392.0
2. Fertilizers—P_2O_5	0.98 million	43.4
3. Caustic Soda	0.40 million	53.6
4. Soda Ash	0.36 million	24.0
5. Sulphuric Acid	2.00 million	23.4

The actual implementation against the above estimates may have to be revised drastically downwards on account of the foreign exchange stringency if serious effort at import substitution is not made.

It is very important from the point of view of import substitution that the designing of the chemical plants, as far as possible and practicable, should be done indigenously, because this would not only save the foreign exchange on the engineering of the plants, but when the designing is indigenous there can be maximum utilization of indigenously available materials and equipment.

To illustrate the point, specific cases of sulphuric acid and caustic soda industries have been studied with respect to the achievements and future goals for import substitution.

Sulphuric acid plants

Before designing of sulphuric acid plants was taken up within the country about a decade ago, most components of a sulphuric acid plant (except perhaps for straight M.S. fabricated vessels) used to be imported. The

total investment as well as foreign exchange requirement were considerably reduced once designing of these plants was taken up indigenously. A progressive utilization of indigenous materials and development of the manufacture of various components in India have led to a stage when every thing except only a few components valued at less than about 10 per cent of the total cost of the plant (at least for sulphur burning plants of up to around 100 tonnes/day capacity) are now indigenous. At present only the following components for a sulphuric acid plant need to be imported:

1. Acid and sulphur pumps and valves
2. Air blowers
3. Instruments
4. Economizer pressure parts

This rapid import substitution has been possible largely due to designing of these plants in India. The designs have been adapted, where necessary to suit indigenously available materials. For example, in foreign countries the plants are designed for SO_2 gas concentration up to 10 per cent being produced in the sulphur burner. In order to use the indigenously available lining materials, the plants are designed to produce only 7–8 per cent SO_2 gas so that excessively high temperatures are not produced in the sulphur burner.

Even these components are now being indigenously developed and with a little effort in trying out the indigenously made components and improving them wherever required, it should be possible to have almost completely indigenous sulphuric acid plants. It is the author's opinion that without taking up indigenous designing of these plants, this degree and pace of import substitution would not have been possible.

Up till now all sulphuric acid plants in India have been based on imported sulphur as the raw material. With the present acute foreign exchange shortage of the country as well as the world shortage of this raw material, the importance of using indigenously available sulphur bearing materials like iron and copper and zinc pyrites and gypsum is being felt. Even though initially the know-how for plants for using these raw materials may have to be imported if emphasis is laid on indigenous designing, a rapidly progressive import substitution of the components should be possible. It is the author's opinion that with the designing knowledge and experience on sulphur based plants available in the country and with the development of indigenous materials and equipment for these plants, it should be possible to indigenously manufacture at least 50 per cent (by value) of the plant and machinery required for pyrites and gypsum based sulphuric acid plants and with a systematic effort at import substitution this percentage can be rapidly improved.

Caustic soda plants

The indigenous designing and engineering of caustic soda plants is even of a more recent origin than that of sulphuric acid plants. That is why even now a considerable portion of the plant and equipment for these plants needs to be imported. However, fairly good progress has been made even in this field, in a very short time.

The Plant and Machinery Panel of the Development Council for Inorganic Chemical Industries studied in December 1964 in detail the present

state of development in this field and arrived at the conclusion[2] that considerable development and machinery for caustic soda plants in the country and that as a result considerable portion of equipment for salt handling, brine preparation and purification, evaporation of caustic liquor from diaphragm cells, chlorine liquefaction, storage and bottling plants, and caustic fusion plants using cast iron pots are already available in the country. It is very pertinent to make a special note of the following conclusion of this Panel: "It was felt that the contention of some of the foreign designers that performance guarantee cannot be given unless their electrolysis plants are integrated with their own design of brine purification and chlorine liquefaction units is untenable."

Up till now a major part of the caustic soda capacity in the country has been based on mercury cells. Mercury cells have the decided advantage of giving rayon-grade pure caustic and also of a lower cost of production as long as the mercury prices do not become fantastic (above £200 per flask). However, on account of the mercury having to be imported, in view of the acute foreign exchange situation serious thought has to be given to the utilization of diaphragm cells, at least where non-rayon grade caustic is required.

An example of achieving maximum import substitution by indigenous designing is in the chlorine liquefaction plant[3] where instead of using low pressure and very deep refrigeration for which the refrigeration compressors would need to be imported for quite some time, the medium pressure medium temperature liquefaction can be selected where single stage refrigeration compressors, which are already started to be manufactured in India, can be utilized.

Importance of standardization

While discussing the development of design of chemical plants in India and its role in import substitution in the context of the current defence requirements and foreign exchange shortage, it will not be out of place to stress the importance of standardization in the designing of chemical plants. By standardizing plant capacities, process designs, design procedures and proforma and specifications of equipment and materials considerable saving can be made in the plant costs and period of completion. Standardization of components and equipment specifications is of great help in indigenous development of hitherto imported equipment and materials. If very few numbers of very many different items are required, the incentive for indigenous development is not so great. However, if with the rationalization and standardization of sizes more numbers of less varieties of sizes are required, there is greater commercial incentive for indigenous development.

Conclusion

It is seen that in view of the current acute foreign exchange shortage in the country, especially on account of our defence requirement, in order not to slacken the pace of development of the chemical industry, it is very essential to make systematic efforts at import substitution. Further it is seen that the import substitution can be very rapid and effective if the designing of the chemical plants is taken up in the country itself. In that case sometimes, when necessary, the designs can be modified to suit indigenously available equipment and materials. The examples of sulphuric acid and caustic soda plants discussed herein show that by indigenous designing a high degree of import substitution can be rapidly achieved.

It is felt that even for plants where it is necessary to get the know-how from abroad, we should endeavour to take up as much of the designing work as possible within our country, in order not only to save the foreign exchange on the engineering, but also to ensure that the designs are based on the maximum utilization of indigenous resources.

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Gaps in the Facilities of Chemical Plant Design in the Country

M. D. VIJAYARAGHAVAN
Dorr-Oliver (India), Ltd
Bombay

To achieve self-sufficiency in this vital field of development of chemical and allied industries in India, considerable efforts have been and are being made to manufacture the various equipment needed. But, as it is well known, a chemical plant is just not an assembly of various equipment and equipment themselves are not something standard which can be taken up for manufacture in any manufacturing shop with modern facilities for manufacturing complicated and large equipment. There are some vital gaps which have to be covered for both equipment and plant design before the design and supply of chemical plants on turn-key basis with the maximum indigenous content can be undertaken in the country. In this paper, an attempt is made to outline some of these shortcomings and suggest measures to overcome them to enable us to reach the goal of self-sufficiency in Chemical Plant Design in this country.

Process know-how for chemical plants

For many processes except those related to production of basic and intermediate chemicals, we are still dependant on foreign process know-how. While it is true that we have to depend on foreign know-how for many years to come, if a conscious effort is made to pool the knowledge and experience available in the country, then it would be possible in certain cases to use indigenous know-how particularly when same types of plants are likely to be built. For example, in the field of most of heavy inorganic chemicals, we do not require any foreign process know-how as we have now accumulated design and operating experience within the country. Even for processes like ammonia and urea, several plants have been built in India and the experience gained with these plants could be made the best use of in developing indigenous know-how for design of these plants with or without the assistance of foreign technical collaborator. Certain other chemical plants in the field of petrochemicals, synthetic fibres, elastomers etc. may still require for some years to come the foreign know-how till such time as we build up sufficient experience in the country. It is only a question of time, before our dependence on foreign know-how could be reduced to the barest minimum. In order to accelerate this, the following steps could be taken :

(a) The foreign companies having the foreign process know-how should be encouraged to invest in or set up joint ventures in India, so that the know-how could be paid for in Indian rupees to the maximum possible extent. These foreign companies should also be encouraged to run their organizations in India with Indian personnel, so that Indian talent could be developed and trained in this vital

field of process know-how. Even if certain amount of foreign exchange may have to be paid to foreign companies for this process know-how, they could do the basic and detailed engineering in India, thereby reducing the foreign exchange needed for the engineering fees. If the basic design work for Indian projects has to be done abroad, the foreign companies could get their Indian engineers work in their Design Offices abroad, so that not only the cost of engineering is reduced but experience of the Indian engineers is built up.

(b) While it is true that the technological progress is making many hitherto well-known processes obsolescent, for India where increase in production at the earliest is most important, even older and intermediate technologies on which we already have some knowledge and experience could be used with great advantage. While we should look into the possibility of adopting the latest know-how, this aim should be tempered with the awareness of advantages resulting to India from the use of older and intermediate process technologies suitable for the raw materials, operating conditions and scale of operations prevailing in India. This would reduce our dependence on latest foreign process know-how and thereby reduce the foreign exchange component and increase the factor of self-sufficiency. Once the production targets are achieved by our own efforts or with the help of foreign firms, we could improve the design in the interest of higher efficiencies. Here again, automation could be kept to the minimum possible extent in conformity with the process efficiency and more sophisticated instrumentation control could be used in conjunction with the future growth of instrumentation technology and industry in the country, so that we reduce the import content of the plants to the barest minimum.

(c) While the economies of scale dictate the need for setting up plants of as large a capacity as possible, both from the point of view of using the indigenous process know-how as well as from the need for import substitution and early production, it may be advantageous to reduce the unit capacities of plants to a more manageable level with maximum indigenous content. With smaller unit capacities, the local shop facilities could be most advantageously used for building smaller equipment needed and the problems of transportation of equipment from the shop to the site could also be minimized. It may also be easier to procure raw materials and dispose of the finished and waste products with smaller capacities than with larger capacities which the economies of scale would dictate. From the point of view of Indian procurement, certain equipment like elevators, conveyors, blowers, grinders, boilers, etc. cannot exceed certain capacities and sizes, and if it is our intention to keep imported components to the minimum, it is essential not to exceed certain capacities for these plants. Therefore, it does not automatically follow that we should go in for the largest size plants as may be designed in Europe, USA, or Japan. We can use more indigenous process know-how and experience with smaller capacity plants.

(d) The engineering and design organizations either foreign or Indian, should try to closely work with their various national laboratories and other Indian research & development institutions, in order

to see whether the process know-how developed or modified by these laboratories could be used for a commercial size plant and if so, the indigenous process know-how, could be used wherever possible to build a pilot plant or a commercial size plant with the help of Indian or foreign engineering and design organizations.

Techno-economic feasibility studies of such processes developed by national laboratories should be carried out to determine whether or not such processes could be profitable, before deciding to build plants based on this know-how. The Indian or foreign consulting engineering organizations established in India can play a vital role. While the process responsibility would then vest with the national laboratories or such research & development institutions, the plant design responsibility would be that of the engineering and design organizations.

(e) In spite of this possibility of developing indigenous know-how, it would still be found essential to import the know-how for several processes for many years to come. The foreign exchange spent for the purchase of these know-how would generate considerable production and contribute to much greater savings of foreign exchange in the long run, and therefore any reasonable amount of foreign exchange for the import of process know-how should be freely allowed and without delay. Such know-how now imported may become indigenous in the long run and we could with the experience gained and in cooperation with the foreign technical firms, even export it to other developing countries in Africa and Asia. The example of Japanese design engineering firms appears very commendable in this regard. However, the basic and detailed engineering should be done in India in order to use the Indian talent and facilities to the maximum possible extent. In order to expedite the import of necessary know-how, a special high powered committee constituted by the Government can screen such applications for the import of know-how, so that sanction of foreign exchange is accorded most expeditiously. It would be best if foreign exchange needed for this purpose is allowed from the free foreign exchange resources of the country instead of special Aid India Club or other long-term credits where the formalities involved are very time consuming.

(f) While it is no doubt true that we should do all we can to encourage our national laboratories and other research and development institutions to develop indigenous know-how, this should not be the reason for denying facilities for purchase of foreign know-how where it is more advantageous and quickest to do so. Research and development takes time and we cannot afford this delay when our main aim is to build up our production capacity rapidly. So development of industries based on foreign know-how as well as development of indigenous know-how should proceed simultaneously and one should not be delayed on account of the other.

(g) Payment for the know-how should be either based on a one time lump sum fees or spread over a limited number of years, the latter being preferable as this would assure a continued interest in the foreign company contributing the know-how. It would also be best to encourage the foreign technical collaborator also to financially participate so that his interest in the success and growth of the project is assured and his knowledge and experience are made available over a long period of time.

(h) Those foreign specialized organizations who are interested in setting up their facilities in India, should be given preference over those organizations who are interested mainly in selling complete chemical plants based on maximum import content.

(i) Foreign or Indian consulting and design engineering organizations should be set up and encouraged as their role is as vital if not more than that of manufacturing establishments.

Equipment design facilities

While it is true that shop facilities exist in India for manufacture of specialized, complicated and large equipment, one of the most important gaps is the absence of equipment design facilities. Several equipment in the chemical plant except those like conveyors, elevators, pumps, motors, etc. are custom built and have to be specially designed for the application and capacities in view. For example, while it would be possible to get a heat exchanger or an evaporator or an agitator manufactured in India, if manufacturing drawings are given to the shops, we have to still depend on foreign companies to give us the design and shop drawings. It is therefore important to encourage foreign and Indian organizations to set up equipment design facilities in India. For any given unit operation of heat transfer, distillation, evaporation, agitation, drying, etc. facilities should be available within the country for sizing and designing the equipment needed for this purpose. For example, in the field of classification, thickening and filtration, facilities are now available within India to design the equipment needed and to get it manufactured according to its design. The same cannot be with regard to other equipment like agitators, evaporators, crystallizers, dryers, etc. Therefore, it would be very essential to create the necessary design facilities within India in order that we can get these equipment designed and manufactured within the country. If we depend on foreign suppliers who do not have design facilities within the country, it may or may not be possible to get the equipment manufactured in India even though the shop facilities are available for this purpose, as the foreign machinery supplier may not be too willing to give the design information and drawings. Therefore, it is very essential to set up joint ventures in India with foreign specialized firms to get the equipment design and manufacture done within the country. For the same reason, it is not possible to get any one shop to manufacture a complete range of different types of custom-built equipment needed for the plant, as the specialized equipment could be manufactured only on the basis of equipment design know-how which will not be available to a manufacturing establishment. Therefore, it may be worthwhile to encourage those organizations who would concentrate on equipment design and would farm out the equipment for manufacture in the existing shops. The function of the Equipment Design Organization would be to select, size and design the equipment for a particular application and prepare the manufacturing drawings which would then be handed over to any large shop for manufacture. The responsibility for equipment design from the process point of view would rest with the expert design firm, while the responsibility for mechanical soundness would rest with the manufacturing shop.

Facilities for the execution of the project

While with the creation and development of consulting engineering or process design and engineering organizations and equipment design

organizations, most of the existing gaps could be covered, it is also essential to have general engineering and contracting firms who would be willing to undertake the execution of the project from the preliminary design stage to production. This function can be carried out also by the process design engineering firm, but in many cases purely engineering and constructing organizations take up this work. They specialize in ways and means of proper programming and coordination of the project work at the design office and at site which involves process and plant engineering, equipment engineering, civil works, electrical engineering, piping, procurement, construction and erection. These organizations may or may not have their own processes but would undertake to build any plants based on the process know-how and design facilities of other organizations. They would function effectively as a liaison between the actual user and the various design firms, vendors and contractors. They would function as a vital unifying link with central responsibility, between the owner or actual user. It is very useful to promote formation of such organizations within the country. It may be said that the industries themselves can undertake this work, but as the main function of industries is production, taking up this responsibility might dilute their work and also impair the efficiency of project execution which itself is a very specialized field. Chart 1 illustrates the functions of the various organizations involved in the execution of a large project.

Commissioning of the plant

Once the plant has been erected, the commissioning of the plant till the guarantees are proven, is the responsibility of the process design engineering firm along with the general engineering and contracting firm. It is essential to build up the experience of Indian engineers to do this commissioning so that after the first one or two plants, the other plants would be commissioned by Indian engineers. Here again, the foreign firms who have Indian facilities would undertake to train the Indian personnel for commissioning the plants and therefore it would be essential to encourage those foreign firms who are prepared to set up organizational facilities with Indian personnel in India. In fact, it should be possible for the experienced Indian engineers to commission plants even in other countries and thus acquire more experience and also earn reputation and foreign exchange for the country.

Service after commissioning of the plant

Any chemical plant however perfect its design might be, would run into problems sooner or later. To solve these problems effectively at least during a stabilized run for a period of about one year is achieved, it would be essential to have available service facilities within the country. These engineering and design organizations who have Indian establishments can no doubt provide these services in a continued manner. This is very essential and important as it would be very difficult to call on foreign technicians to help us out at short notice.

Another problem which confronts many industries today, is the availability of spare parts. Unfortunately, in our country, we have equipment and plants designed and supplied from almost all over the world. It is therefore difficult to obtain spare parts for these equipments which might have been obtained from USA, western or eastern Europe or Japan. While this problem of obtaining spare parts for the equipment already

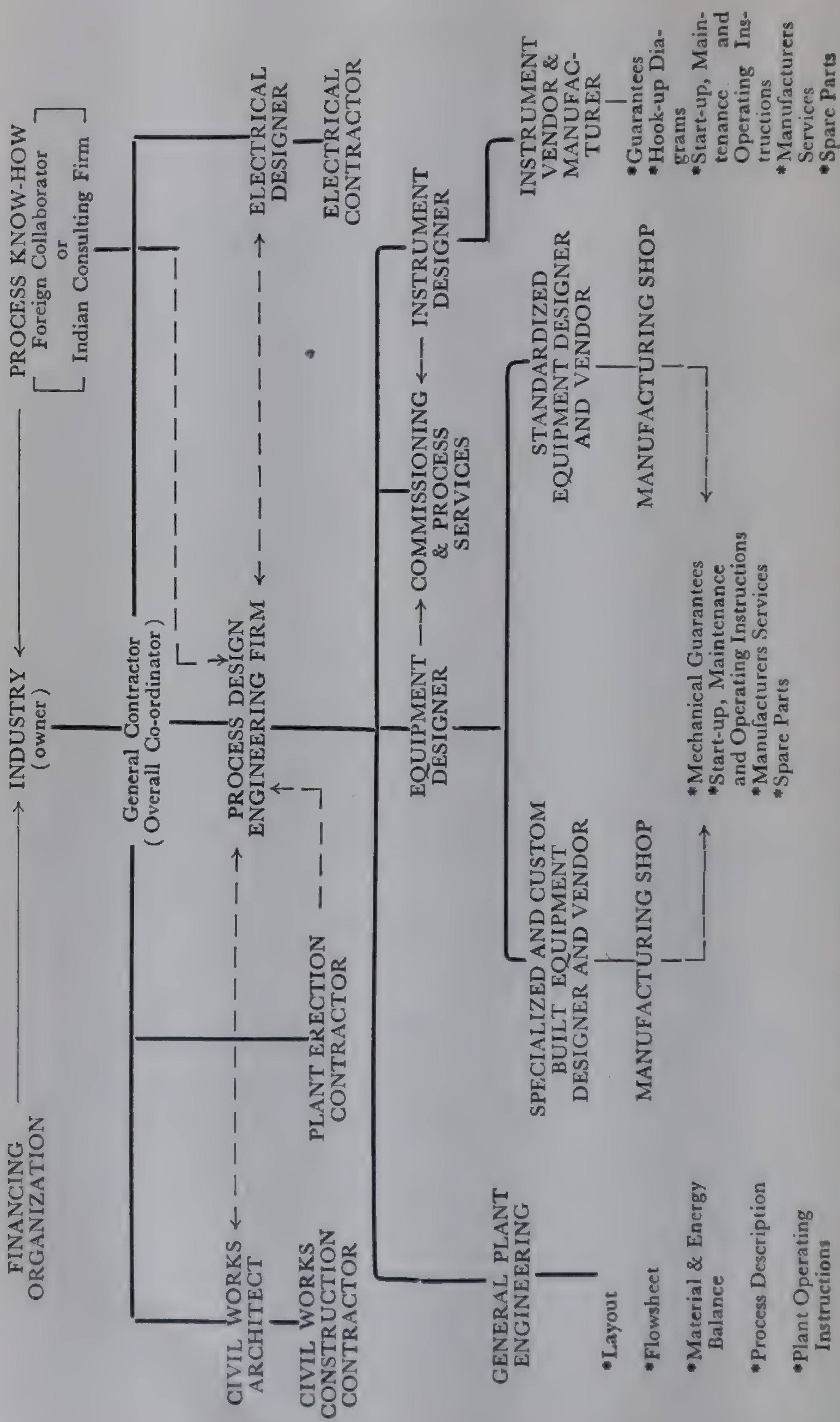

CHART 1—SUGGESTED ORGANIZATION CHART FOR PROJECT EXECUTION

imported from different sources would continue to exist for several years to come, in the future this problem would be reduced in proportion to the availability of equipment of indigenous manufacture. This is all the more reason for us to strive to achieve self-sufficiency in design of equipment based on Indian conditions. The equipment design firm would make maximum use of the components available within India and improvise wherever necessary so that the equipment contains maximum indigenous content even at the sacrifice of some efficiency and performance. Our aim should be to achieve the best possible performance and efficiency in conformity with the available raw materials and components.

Another gap which is well known, is the non-availability of certain raw materials for chemical plant fabrication, like for example, stainless steel, special rubbers, special alloys, adequate plates for pressure vessels, etc. This non-availability and the shortages would no doubt be overcome in course of time when these raw materials are likely to be produced within the country. However, it should be the endeavour of industries as well as the consulting design and engineering firms to use the indigenous raw materials as substitutes even though the substitutes may not be as good as the ideal material of construction. The rubber-lined equipment can replace stainless steel equipment although its life may not be as good. The growth of the industry for plastic and synthetic building materials should also make available to the Indian Industry several substitutes to those metals and alloys which have to be imported. For example, polypropylene, PVC, other polyesters and synthetic rubbers, which could be produced from the petrochemical industries could replace for specialized application other materials of construction which we are now depending upon from imports. Therefore, wherever possible, we should try to utilize indigenous raw materials both natural and synthetic, so that our dependence on imports is greatly reduced over the long run. In order to provide for the imported components and imported raw materials which we cannot still do without, we could further intensify our exports of engineering goods to other countries to earn foreign exchange to at least take care of the imported components of the equipment needed for the Indian industries.

The above, in the author's opinion are some of the vital gaps and problems in the field of Chemical Plant Design, which have to be solved before we can undertake to build plants on turn-key basis based on maximum indigenous content.

Capital Equipment for Chemical Industry

B. K. BANERJEE, R. B. BARTON & D. R. SUD
Central Engineering Dept, ICI (India)
Calcutta

The chemical industry is one of the largest and fastest growing in the country and the establishment of additional heavy chemical manufacturing units such as fertilizers, explosives, oil refineries and petrochemicals complexes requires a capital expenditure of several hundred crores of Rs a year. The engineering materials and equipment to build these plants will make great demands on limited foreign exchange resources. Manufacture has improved considerably over the last decade and there is now much less dependence on imports. Nevertheless, the situation is far from satisfactory and there is a tremendous task ahead. At present, about 40 per cent of our foreign exchange expenditure is used for the purchase of capital equipment and spare parts for new projects and existing industries. Much more can be done to make better use of our own resources and develop them in the right way.

Steel

The first requirement for the manufacture of any commodity is a ready supply of basic materials. For this reason prime importance was given in the formative years of India's industrial expansion to the manufacture of steel. During the last ten years, steel production has increased from 1.3 million metric tons to 4.3 million metric tons and plans are in hand for it to be substantially increased, over the next few years. There is now a basis for the development of the engineering manufacturing industry but a range of alloy steels is required, particularly for chemical equipment.

Non-ferrous metals

In the field of non-ferrous metals, lead, copper, zinc, tin, nickel, etc. the position is less satisfactory and the major portion has to be imported. On the other hand, locally produced aluminium is available in substantial quantities.

Plastics and ceramics

There are a great many other materials required for the manufacture of modern engineering equipment, such as graphite, porcelain and the whole range of plastics. These are either not produced at all or are in short supply. Not until the plans for the petrochemical industry mature can we look forward to a significant increase in the production of such materials as PVC and acrylic fibres.

Cement

Various governmental measures have acted as a disincentive to the expansion of the cement industry and the acute shortage of cement causes expensive delays and dislocations in construction work.

Structural steel work

Despite the large increase in country's output of rolled structural sections, it is still in short supply. This frequently results in buildings being erected to suit the steel sections available rather than from optimum civil engineering design considerations and can result in an increase of 20 per cent to 30 per cent in the weight of steel used.

Chequered plates, corrugated iron sheets and galvanized sheets are available but deliveries can be anything up to 24 months.

Vessels

The chemical industry requires a large variety of vessels for both storage and process. Some of the leading foundries have supplied large iron castings for reaction vessels, fusion pots, etc. weighing up to 10 tons. Steel castings are also available and special composition castings are under development. Die castings can also be provided but present capacity is limited.

Facilities for fabrication from mild steel, stainless steel and aluminium are growing rapidly. To achieve this, it has been necessary to introduce special fabricating techniques such as argon-arc and submerged arc welding and radiographic examination of joints. Complicated fabrications such as stainless steel autoclaves with external jackets, internal coils and agitators are now being undertaken satisfactorily.

Vessels are frequently lined to prevent corrosion. Lead and rubber linings are readily available and glass lining is being developed. It is also possible to obtain lining with special composition stainless steels although the material has to be imported.

It is difficult to obtain locally made chemical vessels for pressures above 500 p.s.i.g. A limitation in size is imposed by the lack of facilities for stress relieving.

Piping and valves

To supply services and feed materials to these vessels a very large quantity of piping is required. Indeed, it is not unusual for the cost of piping to be as high as 10 per cent of the main plant items.

Welded mild steel tubes to IS : 1239, ranging from 1/2 in. to 6 in. are now available but the range and supply of seamless hot finished or cold drawn tubes to BS 806 Class 'B' is very limited.

Associated with the tubes are fittings for connecting them together, and valves for isolation and control. Screwed M.S. and G.I. pipe fittings are obtainable, but manufacture of compression fittings have not yet started. Good progress has been made in recent years in the manufacture of valves for various duties and for working pressures up to 200 p.s.i.g. This includes valves required for service in steam lines. Stainless steel flanged valves of acceptable quality for low pressure service are also being produced.

Pumps

To convey fluids from one vessel to another the most common method is to use a pump. These are as diverse as the duties they have to perform and the materials they have to handle. For water and non-corrosive liquids a large range of good quality pumps are now being offered by Indian manufacturers; production of pumps for handling slurries has also commenced. As yet it is not possible to obtain pumps for use with corrosive liquids or special duty pumps for such things as metering and high pressure discharge. These must still be imported.

To convey gases, the equivalent of a pump is a compressor. These can be obtained for air and non-corrosive gases only, and the range is limited to low and medium duties. Air blowers are also available but gear boxes for heavy duty fans used in cooling towers are still imported.

Boilers

Boilers are now being built up to 500,000 lb./hr and a pressure of 1000 p.s.i.g. using only a small percentage of imported materials, mainly boiler tubes, mountings and liquid fuel burners. Both oil-fired boilers and coal-fired units, complete with coal and ash handling equipment, are available. Packaged boilers are also made but transportation problems limit their capacity to 24,000 lb./hr. Water treatment plants for clarification, filtration and demineralization can also be supplied.

Electrical equipment

In India, the electrical manufacturing industry is one of the most energetic and progressive. A good selection of distribution and motor control gear up to 11 kV. is available, and several manufacturers list motors up to 300 HP as part of their standard range. In the heavy electrical field, too, great strides are being made and impressive plans have been formulated for future development. Most electrical equipment made in India is based on European design and, at its best, the quality is comparable with any imported equivalent.

There is, however, one field of manufacture in which progress has been rather slow, namely flameproof equipment. Apart from a few relatively small HP motors, it is still necessary to import a very high proportion of it.

Instrumentation

The chemical industry is one of the most advanced in the use of automatic and semi-automatic processes and requires a large number of pneumatic, electrical and electronic instruments. So far, manufacture of process control instruments in India has been limited to simple indicators and recorders and a few ON/OFF or proportional type controllers. In a recent survey for a large project it was found that over 90 per cent of the total instrumentation would have to be imported.

Practical considerations for the future

From the standpoint of the chemical industry the overall view is by no means discouraging. In drawing up a catalogue of this kind, what is available tends to be taken for granted and the shortcomings emphasized. It is indeed the object of this paper to highlight those which are important and to suggest priorities for the next stage of development in the engineering

industry on which progress in the chemical industry vitally depends. Clearly there are major gaps in basic facilities : forging capacity, pressing capacity (particularly dished ends) and metal extrusion must all go to the top of the planners' list. But in finding resources for them the need should not be overlooked of foreign exchange to keep up imports of special alloys and components for existing fabrication and assembly work. However, a lot could be done even as the engineering industry stands today to meet the industry's requirements of capital goods.

First, and as a strictly practical consideration, standardization must be a cardinal policy. The excellent work now being carried out by the Indian Standards Institution should be continued with ever-increasing vigour. The days are gone when the quality of material could vary and dimensional tolerances be slack. Cottage industry methods may have done in the past but they are not good enough for modern technological processes. These can only be set up with equipment and components of rigid specification and quality and having a proved performance.

The aim is not top quality most of the time but adequate and consistent quality all the time and to get this much greater attention must be paid to control and inspection during manufacture and fabrication. Apart from a few of the larger concerns far too little is being done at present. Control of quality on the factory floor is rudimentary and too much reliance is placed on acceptance testing in a Test House remote in time and place from the event of manufacture. When materials are in short supply, a long delivery date is inconvenient but can be allowed for. If one item has to be rejected when the delivery is eventually made, waiting as long again for its replacement can be economically disastrous. In fact, consistency of quality is allied to regularity of delivery. More than anything else it will ensure effective use of the existing resources.

Next, greater emphasis should be given to the quality of finish. Too often, basically sound engineering equipment is spoilt by poor painting, galvanizing, plating etc. These are necessary not only from the aesthetic point of view but for protection against corrosion and to increase durability, a specially important property in many processing industries where conditions of service may be severe. Some of these finishes are best left to specialist firms, whose growth should be encouraged.

Again, from the purely practical angle, sales of engineering equipment start from catalogues and technical literature and are backed up by technical sales service and a ready supply of spare parts. These are aggressive marketing tools in the hands of an enterprising manufacturer, not merely luxuries of one who has already established himself. For the successful introduction of equipment in the home and in the export market they are essential and not nearly enough has been seen of them yet.

All this can be done in the industry as it is today without massive capital expenditure, import of raw materials or purchase of foreign know-how and it deserves priority because without consolidating ideas and policy within the engineering industry on specification, quality and delivery and acting on a programme of improvement, satisfactory development will certainly be retarded.

The missing link: Chemical engineering contractors

Although the chemical industry has its own engineers and develops its own skills in all branches of engineering, it does relatively little of the design

and construction work for its projects. Even the largest companies find it impracticable and uneconomic to retain comprehensive engineering services of this kind : the design load is too peaky and the in-breeding of technical ideas within the organization would tend to cut them off from world developments. As a result, the last two decades have seen the rise of a new and important kind of company in the chemical and engineering industries, some of whom are now names of international repute. They are the chemical engineering contracting firms who design and build plants from basic know-how which they buy or obtain under licence from the operating chemical companies. These firms have a world market and usually there are only one or two really successful designs in a particular technology at any one time. Today the successful design for ammonia plants is of British origin, for urea plants of Japanese origin, for nitro-glycerine plants one of Swiss and one of Swedish origin, for phthalic anhydride of American origin. The scene is a swiftly changing one as technological innovations occur. No country has a monopoly and each aims to balance the import and export of its technical know-how. India cannot join this international exchange until chemical engineering contractors are set up in business in a big enough way. The basic scientific and technological information is readily available on the international market for all the chemical products of real importance to India over the next ten years. The major effort on the part of engineers, technologists and scientists must be applied to adapting it to Indian conditions and to bringing it swiftly into productive use. The timing could not be better for the rise of this important modern industry of chemical engineering contractors. A few firms, some with useful foreign connections, have already started and in the public sector progress has been made in this direction by the Department of Atomic Energy. Industry and Government must seek means of promoting growth around these points. Without them the link between the engineering and chemical industries that is vital for the speedy erection of large and efficient plants cannot be forged. The lesson offered in this direction by Japan is an important one, and very significant for this Conference. The remarkable economic growth of Japan has coincided with a spending on research abnormally low by any standards. Intentionally, their scientific and technological effort has been applied instead with singular strength of purpose to the adaptation of know-how for immediate industrial ends. This policy has had a surprisingly rich reward. Adaptation has led to technical innovation, a saleable commodity, and as a result Japan has reached a balance of payments for technical know-how with the rest of the World. It is open to India to achieve the same end just as quickly by similar means.

Self-sufficiency in Power Generating Equipment

S. SWAYAMBU
Heavy Electricals Ltd, Bhopal
&
V. KRISHNAMURTHY
Bharat Heavy Electricals Ltd, New Delhi

Introduction

A large Power Development Programme cannot be sustained on the basis of imported machinery and equipment. The absence of an industry for the manufacture of heavy electrical equipment in the country constituted a great impediment to growth. Government was naturally anxious to cover up this deficiency. In the last few years steps have been taken to develop manufacturing facilities for power generation and transmission equipment in order that we become self-sufficient in this vital field. The Bhopal Plant, the first in this series, has started making significant contribution to the indigenous availability of power equipment. It will, however, take 5–7 years from now before the full impact of all the programmes now under way at Bhopal, Hardwar, Hyderabad and Tiruchi Plants is felt. In this paper we present an outline of the manufacturing facilities contemplated and the progress made. We have also touched briefly upon large power transformers and high voltage circuit breakers although they might fall outside the scope of power generating equipment.

Long term power demand

Recently, an energy survey of the country was made by a committee with which experts from USA and some other countries were associated. This Energy Survey Committee established the probable demands for total energy up to 1980–81 for three alternative rates of growth, viz. 5, 6 and 7 per cent growth in national income. The Central Water & Power Commission and the Planning Commission had also worked out the Energy balance based on projected industrial targets and studies on different rates of growth in power generation capacity. Table 1 shows the estimates made by the Energy Survey Committee, C.W. & P.C. (December, 1964) and by a technical committee recently appointed by the Planning Commission.

The average annual addition to the generating capacity as per the latest estimates of the Planning Commission is 2.3, 3.4 and 4.6 million kW. respectively in the Fourth, Fifth and Sixth Plan periods. The requirement of electrical equipment for generation, transmission and distribution of power is dependent on the power programme mentioned above for the next plan periods.

Table 1 — Installed generating capacity to the end of the year

(in million kW.)

Year	Energy Survey Committee*	C.W. & P.C.	Planning Commission
1965-66	—	12.0	10.35
1970-71	21.4	23.0	22.0
1975-76	33.9	45.0	39.0
1980-81	55.7	70.0	62.0

* Based on 7 per cent rate of growth in national income

Manufacturing potential

After protracted examination culminating in an assessment of the requirements by a Committee in 1954, it was decided to set up the first manufacturing unit at Bhopal. The thinking was, however, extremely conservative because neither the future trend of growth nor even the full impact of the First Five-Year Plan had unfolded itself by then. Subsequent review, prior to the formulation of the Third Plan indicated that the annual increase in demand for power generation in 1965–66 was likely to mount up to 2 million kW. and that this figure will gradually rise during the Fourth and subsequent Plans. The developments during the Third Plan for augmenting the manufacturing capacity were conceived against this background. Thus, in addition to Bhopal, it was decided in 1960 to set up two heavy electrical factories at Hardwar and Hyderabad for the manufacture of hydro and steam power station equipment and a high pressure boiler manufacturing unit at Tiruchi. Later, in 1964–65 sanction was accorded for a speciallized manufacturing unit at Hyderabad for circuit breakers up to 400 kV.

Bhopal plant. In the original programme the Bhopal plant was designed to manufacture only hydroturbines and generators besides power transformers, switchgear, industrial motors and traction equipment. Recently, a scheme to manufacture steam turbines and turbogenerators has also been approved and when these plans are completed the plant will be equipped to manufacture the following:

Hydroturbines & Generators		...	500 MW.
Steam Turbines & Turboalternators		...	1200 MW.
Power Transformers		...	3000 MVA. to be increased to 6000 MVA. in Fourth Plan period
Circuit Breakers	11 kV.	...	19000 nos.
	33 kV.	...	300 nos.
	66 kV.	...	100 nos.

The Plant also envisages the manufacture of air blast circuit breakers and for the present their programme is restricted to 25 nos. of 132 kV. and 25 nos. of 220 kV. breakers annually.

The Bhopal plant has facilities to manufacture all types and sizes of hydroturbines and generators with runner diameters up to 6000 mm. The Plant is already supplying 3×33 MW. units for Obra Hydroelectric Scheme, one of the largest size machines in this category and 3×15 MW. sets for Bassi Power House. In addition orders have been received for over

26 hydroturbines and generators for other power stations including 165 MW. units for the Sutlej-Beas Link.

On thermal equipment, Bhopal, after completing the first 3×30 MW. sets, will standardize on 120 MW. sets for four or five years. Thereafter it is programmed to take up production of 300 MW. turbo-sets. The 120 MW. set is a re-heat three cylinder machine with steam parameters 126 atm. and 538°C. The first 120 MW. Turbo-set is scheduled for delivery in 1967–68 and the supplies till the end of the Fourth Plan include 10 such sets.

The plant has facilities for the manufacture of any size and type of transformer, the largest size so far delivered to the customers being 75 MVA., 132 kV. The order book includes 250 MVA., 21/230 kV. for the Nuclear Power Station at Kotah.

Hardwar plant. The Plant is designed to produce annually 1500 MW. of steam turbines and turboalternators and 1200 MW. of hydro-turbines and generators. The Plant will also manufacture large electric motors. The civil construction works in progress will be completed early in 1967. All major equipments have been ordered and their installation will be phased to suit the production programme.

On the thermal side production of the following turbo-sets are provided for:

50 MW.	single cylinder	90 atm.	535°C.	non-reheat
100 MW.	two cylinders	90 atm.	535°C.	non-reheat
200 MW.	three cylinders	130 atm.	565°C.	reheat
300 MW.	three cylinders	240 atm.	580°C.	reheat

Production of turbo-sets of 300 MW. and even higher capacities are contemplated when needed. Manufacture will start in 1967 with 100 MW. sets and the first set is scheduled for delivery in December 1968. Two hundred MW. sets will be taken up a little later and units of this size will be available from the first quarter of 1971. The scope of manufacture at this Plant will include condensers, heaters and coolers. Pumps required for completing these sets are planned for manufacture at the Hyderabad Plant. The anticipated deliveries up to the end of the Fourth Plan is 9 of 100 MW. and 1 of 200 MW. units.

The Plant is designed to produce hydroturbines with runner diameters up to 6600 mm. — perhaps the largest that may have to be catered for. The manufacture of hydroturbines and generators will closely follow the steam turbines and delivery of large hydro-sets is programmed from the middle of 1969.

The rated output of 1500 MW. of thermal station equipment and 1200 MW. of hydro equipment from Hardwar is expected to be reached in 1973–74.

Hyderabad plant. Manufacture of steam turbines, turbo-alternators and certain power station auxiliaries like pumps including feed water pumps, heaters, coolers and piping can be undertaken at this Plant. The output capacity planned for steam turbo-sets is about 800 MW. annually from the smallest ranges up to unit sizes of 100/110 MW. The full output from this Plant is expected in 1972–73. The tooling of this Plant takes into account the production of smaller turbines also for industrial uses,

In the medium and higher ranges, the sizes of generating sets that can be produced are:

12 MW.	single cylinder	40 atm.	460°C.
25 MW.	single cylinder	101 atm.	545°C.
55/60 MW.	two cylinders	90 atm.	535°C.
100/110 MW.	three cylinders	130 atm.	565/535°C. reheat

The Plant is under construction and production in auxiliary shops has commenced; the main facilities for the manufacture of turbines and alternators will be completed in 1966, whereafter production of major components will start. The first 55/60 MW. unit is scheduled for delivery early in 1967. The programme in the Fourth Plan period includes manufacture of $8 \times 55/60$ MW. units and $7 \times 100/110$ MW. units. Hundred MW. units will be available from April 1969 onwards.

The scope of supplies from this Plant will include all the general engineering items including condensers, pumps associated with the turbo-set, cooling water pumps and feed pumps. The Plant will also manufacture and supply inter-connecting piping. It is proposed to increase the output of the pumps and other general items to meet the requirement of turbines produced at Hardwar and Bhopal.

Boiler manufacturing plant at Tiruchi. Power Station boilers complete with mills, fans, precipitators, pipings, high pressure fittings and valves will be manufactured at this Plant. The output in the first stage of development will correspond to 40,000 tons of finished material or 3000 tons of steam per hour which will match a power generating capacity of 750 MW. The Plant has gone into production and its manufacturing programme for 1966 to 1971 will match the production of 55/60 MW. and 100/110 MW. sets at Hyderabad and Hardwar. Plans are underway for enlarging the scope of this Plant in order to increase its output to about 85,000 tons of material corresponding to about 2000 MW. of generating capacity. With the facilities provided, it will be possible to manufacture any type of boilers including those required for 200 MW. and 300 MW. units.

A.V.B. Durgapur. In addition to the Tiruchi Unit, high pressure boilers are also manufactured at the A.V.B. Works, Durgapur. With some additional facilities that are being installed, this Plant is estimated to give an output of 500 MW. of boilers annually. In the Third Plan they have supplied 8×60 MW. boilers for different power stations. During the Fourth Plan their programme will match the 120 MW. turbo-sets proposed to be manufactured at Bhopal.

With the developments envisaged at Bhopal, Hardwar and Hyderabad, the total manufacturing potential that will be created for thermal and hydro generating sets is given in Table 2.

Table 2 — Proposed manufacturing potential for thermal and hydro generating sets

Plant		Steam turbines and generators (MW.)	Hydroturbines and generators (MW.)
Bhopal		1200	500
Hardwar		1500	1200
Hyderabad		800	nil
	TOTAL	3500	1700

Facilities for the manufacture of thermal and hydro station equipment being similar to a great extent, it will be possible to make adjustments in the output capacities of Hardwar and Bhopal to suit the varying proportions in which additional requirements of hydro and steam power station equipment will be needed. Besides, the capacity for thermal equipment at Hardwar has been calculated on the basis of unit sizes ranging from 50 MW. to 200 MW. If, in the later years, the demand is largely for higher sized unit the output from this Plant will increase. Thus the facilities that are being created in these three Plants will adequately meet the country's demand for power generating equipment for the next 10/15 years.

Table 3 shows the progressive production of turbo-generator sets in bhopal, Hardwar and Hyderabad Plants from 1966 to 1981.

In regard to the Boilers, however, the total manufacturing facilities may not match the capacity for steam turbines even after the projected expansion of Tiruchi Unit to 2000 MW. Further studies are being made by the Government in regard to the adequacy or otherwise of the manufacturing capacity for boilers.

Large power transformers. The annual requirement of step up and step down transformers is estimated at 8600 MVA. in the Fourth Plan and 12,000 MVA. in the Fifth Plan period. As against this, the licensed capacity in the country including 6 million kVA. of Bhopal is about 10,000 MVA. While there will be no difficulty in regard to the unit sizes that can be made at the Bhopal plant there may be limitations in handling and testing facilities so far as the other manufacturing plants are concerned. Necessary steps will have to be taken for the manufacture of 400 kV. transformers that may be demanded shortly.

Circuit breakers. The anticipated maximum annual demand for circuit breakers is given in Table 4.

Bhopal has already supplied to different power systems 132 kV. air blast circuit breakers. Their annual production capacity is about 100 nos. of 132 and 220 kV. breakers. Messrs Hindustan Brown Boveri has also a programme for the manufacture of air blast circuit breakers and their licensed capacity for 132 and 220 kV. breakers is 60 nos. annually.

In addition Government of India are setting up a specialized plant at Hyderabad for the manufacture of circuit breakers of ASEA's design. In the first stage of development of this Plant, it is proposed to manufacture air blast circuit breakers, the annual production being 100 nos. of 132 kV., 100 nos. of 220 kV. and 40 nos. of 400 kV. breakers. In the next stage, it is proposed to take up manufacture at this Plant minimum oil contraction breakers of voltages 33, 66 and 132 kV. in adequate numbers. The manufacture of minimum oil breakers will closely follow the air blast circuit breakers. This Switchgear Plant of Bharat Heavy Electricals Ltd, will start delivery of 132 and 220 kV. breakers from October 1966 and 400 kV. breakers when required.

It is expected that these three manufacturing Plants will cover the requirement of E.H.V. circuit breakers needed for the power system. In regard to 66 and 33 kV. breakers, the anticipated production capacity so far planned is 2300 nos. including 400 nos. of Bhopal and 800 nos. of minimum oil breakers programmed at the Switchgear Unit of Bharat Heavy Electricals Ltd.

Table 3 — Programme of manufacture of steam turbo sets in plants under implementation

Unit	1966-67	1967-68	1968-69	1969-70	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81
Bhopal	1×30	2×30	3×120	3×120	4×120	5×120	4×120 1×300	2×120 2×300	3×300	4×300	4×300	4×300	4×300	4×300	4×300
Sub-total for Bhopal, MW.	30	60	360	360	480	600	780	840	900	1200	1200	1200	1200	1200	1200
Hardwar			1×100	4×100	4×100 1×200	3×12×10000 3×200	5×200	2×100 5×200 1×300	2×100 5×200 1×300	2×100 5×200 1×300	2×100 5×200 1×300	2×100 5×200 1×300	2×100 5×200 1×300	2×100 5×200 1×300	2×100 5×200 1×300
Sub-total for Hardwar, MW.			100	400	600	900	1200	1500	1500	1500	1500	1500	1500	1500	1500
Hyderabad	1×12	2×55	4×55	2×55 3×100	2×55 4×100	6×100	7×100	8×100	8×100	8×100	8×100	8×100	8×100	8×100	8×100
Sub-total for Hyderabad, MW.	12	110	220	410	510	600	700	800	800	800	800	800	800	800	800
Estimated total indigenous production	42	170	680	1170	1590	2100	2680	3140	3200	3500	3500	3500	3500	3500	3500

Table 4 — Anticipated annual demand for circuit breakers

Category	Max. annual demand (nos.)	
	Fourth Plan	Fifth Plan
400 kV., 220 kV., 132 kV. and 110 kV. breakers	420	560
66 and 33 kV. breakers	2500	3375

Problems confronting the heavy electrical industry

During the last five or six years there has been intense activity in setting up the three Heavy Electrical Plants at Bhopal, Hardwar and Hyderabad and the High Pressure Boiler Plant at Tiruchi. The experience gained during these years has brought to light a number of problems which are somewhat special for this industry. Some of the more important problems would be discussed in the following paragraphs.

Long development period. Unlike a process industry such as steel or fertilizer, the manufacture of electrical equipment calls for individual designs to meet the customers requirements depending upon the site conditions etc. For example, no two hydroelectric sites are the same and each and every equipment for every power station will have to be separately designed in order to get the maximum advantage of the site conditions. In the case of a steam turbine, it may be possible to adopt a particular size of machine, but even here some variations are inevitable in order to match the equipment with the system and site conditions. In view of the wide variations it will take a considerable time both for the design and manufacturing engineers to gain the experience.

The technology underlying the manufacture of electrical equipment is very intricate and covers a very wide range of scientific and engineering knowledge. For example, in the case of water turbines a special welding techniques for stainless steel and heavy forgings of special steel are required. In the case of steam turbines, techniques relating to high temperatures and pressures, knowledge of austenitic and molybdenum steels and the techniques of design and manufacture of blades are called for. For large generators, knowledge of insulation techniques is very essential. Further, due to continuous research and development, the know-how is changing almost continuously. It would, therefore, be necessary not only to get a thorough insight of the existing techniques, but also to keep abreast of the latest developments.

As the Heavy Electrical Industry has been started in the country for the first time and with a very ambitious programme the skill required of the artisans and the supervisors had to be developed in a very short time. Thousands of men were given two to three years' training in the training schools attached to these projects and were brought on to the manufacturing areas thereafter. Thus the long experience available to the foreign manufacturing organizations does not exist in this country at present and this experience will have to be gained only over a period of years and confidence will be developed after a number of machines of each type is built, tested and commissioned successfully.

As most of the electrical machines are required to function under onerous service conditions, very high quality standards are required to be maintained. This calls for sound manufacturing methods such as providing precision tools, elaborate and expensive test equipment, quality control and inspection of materials, research and development activity, etc. Conforming to such high quality standards would necessarily slow down the rate of growth in the initial years, but there is no alternative to building up of high standards of quality in this industry.

Indigenous substitution

The usual method of establishing the manufacture of a particular product is to start with parts assembly with a fairly high percentage of imported components and gradually increase the indigenous content. In this process it is most imperative that we should cut down imports to the maximum extent at the earliest possible time. There are two distinct lines of import: (i) for manufactured components and (ii) for raw materials. The reduction in the first item could be effected by undertaking the maximum component manufacture in the main factory itself, but it would be preferable to sub-contract as many small items as possible to ancillary industries. This is a somewhat slow process as the ancillary industries have started only more recently and in view of the special quality requirements of this industry they are not able to meet our entire demand. At the same time manufacturing a very wide variety of components in the heavy electrical factories takes a considerable amount of development time and hence import is inevitable for a certain period.

In regard to the raw materials and intermediate products most of the ferrous and other items are being developed within the country. For example, a number of insulating materials are already available and considerable development work is being done at Bhopal, for new products. Heavy Engineering Corporation, Ranchi, may soon be in a position to supply a part of the requirement of large castings and forgings. In order to meet the demand of Heavy Electrical Industry fully a Central Foundry-Forge Plant is also being set up. Bhopal factory can undertake stainless steel fabrication. However, there are certain items such as special grades of covered copper, cold rolled silicon sheet steel, which will continue to be imported for many years, as we do not produce these items inside the country. For generator stator laminations, silicon sheet steel of appropriate quality is not available. Similarly, alloy steel tubes for boiler manufacture and copper and brass tubes for condensers and coolers are difficult to obtain indigenously. Boiler quality plates are also in short supply. Some development work is being started on substituting copper by aluminium, but there are definite limits for this work in the electrical machines industry. The work of indigenous substitution is essentially for the Indian engineers and scientists to undertake as very little help would be available from the foreign collaborators. The success of substitution would be gradual, but constant effort in the way of research and development will be required.

Cost of indigenous equipment

Often comparison is made between the cost of electrical equipment made in India and the cost of imported equipment from various countries and this invariably leads to the conclusion that the Indian costs are substantially higher. Such a comparison is not always fair to newly established

Indian industries involving considerable amount of first cost, expensive collaboration charges, training expenses, etc. In working out prices for customers, such initial charges are usually spread over a long period of years. Nevertheless the high cost of indigenous raw materials as well as duties payable on imported raw materials contribute to the higher prices. At the same time the low level of production and the somewhat low productivity of labour in the early years are other adverse factors for the Indian Industry. Certain plant and equipment such as impregnation Plant, Test Plant, etc., Large Bending Rolls in Boiler Shops and other unique machines will be utilized only for a fraction of their available time and yet a minimum of one each has to be installed. The foreign companies could utilize such equipment better by diversified and higher volume of production. Besides, it has to be recognized that the export prices of many countries are often subsidized or kept very low (being priced on the 'marginal cost' principle) in order to utilize certain idle capacity in their works. It is common knowledge that the internal prices of this equipment in those very countries are maintained at a much higher level than the export prices. One other factor which adds to increased cost (by way of higher inventory and interest charges) is the comparatively long manufacturing cycle of our products during the initial years. This also accounts for the somewhat longer delivery periods which are being offered by the Indian factories. Hence the high level of cost of Indian equipment has to be recognized in its true perspective. In the course of next few years, however, when the output of different factories reach their optimum levels and technical and labour efficiency is built up adequately, there is every reason to hope for cost which may bear comparison with many other countries — a fact which may possibly help us to consider export of certain products.

Close cooperation between the manufacturer and the customer

The process of becoming self-sufficient in power plant and equipment will be hastened by means of close cooperation between the electricity boards who are the main purchasers of equipment and the manufacturing units which are mainly the heavy electrical plants. Some of the specific methods for achieving this are discussed below:

Variety reduction. For every item of equipment we should endeavour to reduce the number of types and ratings. This would help the manufacturer to reduce cost and improve the delivery period. This would, of course, call for some sacrifice of established practice, flexibility and equipment performance. The Power Boards have been accustomed to certain wide range of designs and products supplied by foreign countries over the years, but the heavy electrical factories are somewhat restricted in their own choice of designs, types and ratings of equipment as a result of the scope of collaboration established by Government. Their products could, by and large, be suitable to our power system, but there can be a few exceptions. In such cases, the accommodation of the Power Boards is particularly necessary to accept the type of products made by the Indian Industry with a minimum of deviation.

With a view to minimizing the learning period and hastening the output level, only certain types of equipment have been chosen during the initial stages. It would, therefore, be most helpful for establishing this industry if the customers are in a position to accept such equipment even at some inconvenience. Some of the following examples will elucidate this aspect of the problem.

Transformers. The standard voltage and mVA. ratings as per the Indian Standards are being followed for transformers up to 220 kV., in the Bhopal factory. In respect of the connections the star/star tertiary delta has been taken up as a standard line of manufacture. Tap changer of one particular type has been adopted. The usual methods of cooling have been provided for. It is interesting to record here that as a result of discussion and understanding between the supplier and the customer, it has now been possible to standardize on these varieties and this has found almost total acceptance by the power systems, barring a few exceptions where the conditions are inescapable. This has lead to a happy situation that the entire range of transformers required by the country could be met by the designs and the types that have been standardized at Bhopal.

Steam turbines. Having regard to the rapid growth of interconnected power systems in India, it has been found at the very outset that there is little demand for thermal plant of small sizes. It has, therefore, been decided that after making three 30 MW. sets (more as a learning exercise), Bhopal should take up the manufacture of 120 MW. sets and after completing about 15 to 20 sets, the manufacture of 300 MW. sets should be undertaken. Hardwar factory will be starting with 100 MW. sets and soon be changing over to 200 MW. and 300 MW. sets. Similarly, Hyderabad will concentrate on 100 MW. units after the initial manufacture of 8×55 MW. sets. Thus, during the Fifth Plan period machines of 100/120, 200 and 300 MW. would be available for the power systems. Obviously, it would be in the overall interest that the power systems are, more or less planned having regard to the availability of these machines. It may happen that in a few of the very large power systems there may be technical and economic justification for units larger than 300 MW., but a decision in this respect should be taken in the context of the country's ability to produce such equipment.

Water turbines. As pointed out earlier, this equipment will have to be designed and built to suit individual site conditions. Nevertheless it would still be possible, by increasing or decreasing the number of units in any particular location, to adopt designs of equipment which lend themselves for easy manufacture inside the country. For example, purely economic considerations may point out the need for say 200 MW. machines for a particular site which may prove to be beyond our ability to manufacture and may also warrant a large amount of import. In a case like this we should consider installation of a larger number of machines of a smaller rating which may be within our capability to manufacture. It is also likely that certain designs would have been already developed and tools for them manufactured. If, by some adjustment, the same machines could be adopted for the new project, there would be considerable economy in production.

Boilers. Like water turbines, boilers will also have to be designed to suit individual site conditions. Here also it may be possible to evolve methods by which changes in designs are reduced to minimum, thereby maximizing the output. Regenerative type of air preheaters might be ideal for boilers of 100 MW. and above, but owing to the attitude of the patent holders of this design it has not been possible to introduce the manufacture of this item in India. The indigenous boilers will, therefore, be supplied with tubular air preheaters with consequential extra space and maintenance. Otherwise it would involve import of regenerative type of preheaters at very high costs.

In view of the comparatively longer time taken for indigenous manufacture owing to new designs, difficulties in procurement of materials etc., it would greatly help the industry if orders are placed as much in advance as possible. Three years for thermal equipment and four years for hydro station equipment would ensure adequate time for planning and maximizing the indigenous content.

The above examples indicate the need for close understanding between the electricity boards and the manufacturing units of power plant and equipment. In fact, all items of cost of an equipment will have to be paid for by the customer. Such contribution as the customer makes for variety reduction and economy in design and manufacture would all flow back to him in the form of reduced prices. It may also bring to them many incidental advantages of reduction in spares, improved delivery periods, shorter erection time and easier maintenance.

In conclusion, it may be emphasized that the manufacture of heavy electrical equipment and their installation and operation should be deemed to be a joint endeavour in the service of the community. To this end, maximum cooperation between the manufacturers and users of power plant and equipment would result in maximum national advantage.

Price : Rs 7.00 Sh. 14/- $ 2.00